92-008504

AIR-CONDITIONING SYSTEM

ABSTRACT

None

REPRESENTATIVE DRAWING

FIG. 1

SPECIFICATION

TITLE OF THE INVENTION

AIR-CONDITIONING SYSTEM

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram showing the entire structure of the refrigerant system of the air-conditioning system according to the first embodiment of the present invention;

FIG. 2 is a schematic diagram showing the operation wherein either only room cooling or only room heating is carried out in the first embodiment of FIG. 1;

FIG. 3 is a schematic diagram showing the operation which is performed when room heat operation capacity is greater than room cooling operation capacity in the first embodiment of FIG. 1;

FIG. 4 is a schematic diagram showing the operation which is performed when room cooling operation capacity is greater than room heating operation capacity in the first embodiment of FIG. 1;

FIG. 5 is a schematic diagram showing the entire structure of the refrigerant system of the modified air-conditioning system according to the first embodiment of FIG.1;

FIG. 6 is a schematic diagram showing the operation wherein either only room cooling or only room heating is carried out in the embodiment of FIG. 5;

FIG. 7 is a schematic diagram showing the operation which is carried out when room heating operation capacity is greater than room cooling operation capacity in the embodiment of FIG. 5;

FIG. 8 is a schematic diagram showing the operation which is carried out when room cooling operation capacity is greater than room heating operation capacity in the embodiment of FIG. 5;

FIG. 9 is a flow chart showing the control flow of the controller of the embodiment of FIG. 5;

FIG. 10 is a schematic diagram showing the entire structure of the refrigerant system of the modified air-conditioning system according to the first embodiment of the present invention;

FIG. 11 is a schematic diagram showing the entire structure of the refrigerant system of the air-conditioning system according to the second embodiment of the present invention;

FIG. 12 is a schematic diagram showing the operation wherein either only room cooling or only room heating is performed in the embodiment of FIG. 11;

FIG. 13 is a schematic diagram showing the operation which is carried out when room heating operation is principally performed in the embodiment of FIG. 11;

FIG. 14 is a schematic diagram showing the operation which is carried out when room cooling operation is principally performed in the embodiment of FIG. 11;

FIG. 15 is a flow chart showing the control flow of the controller according to the embodiment of the present invention;

FIG. 16 is a schematic diagram showing the refrigerant system of the air-conditioning system according to the third embodiment according to the present invention;

FIG. 17 is a refrigerant circulation diagram showing the operation which is carried out when either only room cooling or only room heating is performed in the air-conditioning system of FIG. 16;

FIG. 18 is a refrigerant circulation diagram showing the operation which is carried out when room heating is principally performed in the air-conditioning system of FIG. 16;

FIG. 19 is a refrigerant circulation diagram showing the operation which is carried out when room cooling is principally performed in the air-conditioning system of FIG. 16;

FIG. 20 is a schematic diagram showing the entire structure of the refrigerant system of the modified air-conditioning system according to the third embodiment of the present invention;

FIG. 21 is a schematic diagram showing the refrigerant system of the air-conditioning system according to the fourth embodiment of the present invention;

FIG. 22 is a schematic diagram showing the operation which is carried out when either only room cooling or only room heating is performed in the

embodiment of FIG. 21;

FIG. 23 is a schematic diagram showing the operation which is carried out when room heating is principally performed in the embodiment of FIG. 21 (i.e. when room heating operation capacity is greater than room cooling operation capacity);

FIG. 24 is a schematic diagram showing the operation which is carried out when room cooling is principally performed in the embodiment of FIG. 21 (room cooling operation capacity is greater than room heating capacity);

FIG. 25 is a schematic diagram showing the refrigerant system of the modified air-conditioning system according to the fourth embodiment of the present invention;

FIG. 26 is a schematic diagram showing the refrigerant system of the air-conditioning system according to the fifth embodiment of the present invention;

FIG. 27 is a refrigerant circulation diagram showing the operation which is carried out when either only room cooling or only room heating is performed in the air-conditioning system of FIG. 26;

FIG. 28 is a refrigerant circulation diagram showing the operation which is carried out when room heating is principally performed in the air-conditioning system of FIG. 26;

FIG. 29 is a refrigerant circulation diagram showing the operation which is carried out when room cooling is principally performed in the air-conditioning system of FIG. 26;

FIG. 30 is a schematic diagram showing the entire structure of the refrigerant system of the modified air-conditioning system according to the fifth embodiment of the present invention;

FIG. 31 is a schematic diagram showing the entire structure of the refrigerant system of the air-conditioning system according to the sixth embodiment of the present invention;

FIG. 32 is a schematic diagram showing the operation which is carried out when either only room cooling or only room heating is performed in the embodiment of FIG. 31;

FIG. 33 is a schematic diagram showing the operation which is carried out when room heating operation capacity is greater than room cooling operation capacity in the embodiment of FIG. 31;

FIG. 34 is a schematic diagram showing the operation which is carried out

when room cooling operation capacity is greater than room heating operation capacity in the embodiment of FIG. 31;

FIG. 35 is a flow chart showing the control flow of the controller of the embodiment of FIG. 31;

FIG. 36 is a schematic diagram showing the entire structure of the refrigerant system of the modified air-conditioning system according to the sixth embodiment of the present invention; and

FIG. 37 is a schematic diagram showing the refrigerant system of a related art air-conditioning system.

*DESCRIPTION OF MAIN REFERENCE NUMERALS IN THE DRAWINGS

1: outdoor unit	2: compressor
3: four-way valve	4: outdoor heat exchanger
8: accumulator	19: outdoor fan
9a to 9c: indoor units	10: indoor heat exchanger
11: temperature sensor	13: first connection pipe
14: second connection pipe	20: three-way switching valve

21: first electric expansion valve that is a first flow rate controller

22: third connection pipe

23: second electric expansion vale that is a second flow rate controller

29: gas-liquid separator

30a to 30c: indoor unit operation controllers 33: controller

The same reference numerals will be used throughout the drawings to refer to the same or like parts.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to a multiple room type air-conditioning system wherein a plurality of indoor units are connected to a single outdoor unit, and more particularly, to an air-conditioning system wherein room cooling or room heating can be selectively carried out for each indoor unit, or wherein room cooling and room heating can be simultaneously carried out in all indoor units.

An example of such a related art air-conditioning system is disclosed in the Japanese Utility Model Publication No. 47-22558.

FIG. 37 is a schematic diagram showing the refrigerant system of the related art air-conditioning system disclosed in the above publication. In FIG. 37, a reference numeral 1 represents an outdoor unit of an air-conditioning system. A reference numeral 2 represents a compressor, 3 a four-way valve, 4 an outdoor heat

exchanger, 5 a check valve, 6 an expansion valve, 7 a receiver, 8 an accumulator, and 9 an outdoor fan. These elements constitute the outdoor unit 1. Reference numerals 9a to 9c represent indoor units connected with the outdoor unit 1. A reference numeral 10 represents an indoor heat exchanger, 11 a check valve, and 12 an expansion valve. These elements are first and second connection pipes that connect the indoor units 9a to 9c to the outdoor unit 1. A solid line arrow represents a refrigerant flow in case of room heating while a dashed line arrow represents a refrigerant flow in case of room cooling.

The operation of the aforementioned related art air-conditioning system is as follows. First, in case of room heating only, a refrigerant gas of high temperature and high pressure discharged from the compressor 2 is supplied from the first connection pipe 13 to the indoor units 9a to 9c and is heat-exchanged with indoor air (heated) in the indoor heat exchanger 10 for condensed liquefaction. A refrigerant liquid liquefied in the indoor units 9a to 9c is supplied to the second connection pipe 14 through the check valve 11 and then to the expansion valve 6 through the receiver 7. The refrigerant liquid is depressurized to become a gas-liquid two-phase state of low temperature. The refrigerant is then supplied to the outdoor heat exchanger 4. Since the refrigerant supplied to the outdoor heat exchanger 4 is heat-exchanged with outdoor air, it is evaporated and inhaled into the compressor 2 in a gas state. In this way, the circulation cycle is formed to carry out the room heating. Meanwhile, in case of room cooling, the circulation cycle opposite to that of the room heating is made. In other words, the refrigerant constituting a gas of high temperature and high pressure is heat-exchanged (cooled) with outdoor in the outdoor heat exchanger 4 and then condensedly liquefied. The refrigerant is then supplied from the connection pipe 14 to the indoor units 9a to 9c through the receiver 7.

The refrigerant liquid supplied to the indoor units 9a to 9c is depressurized to become a gas-liquid type two-phase state of low temperature and then is heat-exchanged (cooled) with indoor air in the indoor heat exchanger 10. Thus, the refrigerant liquid becomes a gas state and is inhaled to the compressor 2 through the connection pipe 13.

The rotational frequency of the compressor 2 in case of room heating and room cooling is controlled depending on the driving number of the indoor units 9a to 9c and rated capacity. The outdoor fan 19 is controlled at a maximum revolution per minute. In the aforementioned related art multi-chamber type air-conditioning

system, since all the indoor units 9a to 9c should perform room heating or room cooling, a problem may occur in that heating is performed in a place required of cooling and vice versa. Particularly, if the multiple room type air-conditioning system is provided in a large scaled building, the above problem may occur because air-conditioning load is different per an indoor portion, its periphery, an office room and a computer room. In addition, in case of a lease building, since air-conditioning load is varied depending on a leaseholder, it is impossible to previously divide the building into a cooling zone and a heating zone. To solve this problem, if a room cooling indoor unit and a room heating indoor unit are provided in one room, high cost is caused.

Therefore, the present invention is to provide an air-conditioning system in which room cooling and room heating are selectively or simultaneously performed in each indoor unit depending on cooling and heating requirements of a room provided with each indoor unit even if a plurality of indoor units are connected with an outdoor unit.

In an air-conditioning system according to the first embodiment of the present invention including an outdoor unit provided with a compressor, a four-way valve, an outdoor heat exchanger, and an accumulator, and a plurality of indoor units provided with an indoor heat exchanger, the outdoor unit being connected with the indoor units in parallel through first and second connection pipes, one side of the indoor units is switchedly connected to the first connection pipe or the second connection pipe, and a third connection pipe is provided with a second controller at a pipe path, the third connection pipe having one side connected to the other side of the indoor units through a first flow rate controller, and the other side connected to either the first connection pipe or the second connection pipe.

A modified air-conditioning system according to the first embodiment of the present invention includes a controller controlling operation modes of the respective indoor units and the opening degree of the first flow rate controller, and controlling the opening degree of a second flow rate controller based on the state of a refrigerant of the third connection pipe between the first and second flow rate controllers.

An air-conditioning system according to the second embodiment of the present invention includes a controller detecting operation modes of the respective indoor units and the difference between a set temperature and each room temperature and at the same time determining the operation state and controlling the

volume of the compressor and heat exchange capacity of the outdoor heat exchanger depending on the detected data.

In an air-conditioning system according to the third embodiment of the present invention including a gas-liquid separator provided at the middle portion of a first connection pipe or a second connection pipe that connects an outdoor unit to a plurality of indoor units, one side of each indoor unit is switchedly connected with the first connection pipe or the second connection pipe, and the other side is connected to the gas-liquid separator provided at either the first connection pipe or the second connection pipe through a receiver and a flow rate controller by the third connection pipe.

In an air-conditioning system according to the fourth embodiment of the present invention in which an outdoor unit is connected with a plurality of indoor units through first and second connection pipes, one side of the indoor unit is connected with a first branch joint switchedly connected to the first connection pipe or the second connection pipe, the other side is connected to a second branch joint connected with the second connection pipe through the first flow rate controller connected with the indoor units, the first branch joint and the second branch joint are connected with each other through the second flow rate controller, and a relay having the first branch joint, the second flow rate controller, and the second branch joint is interposed between the outdoor unit and the indoor units so that the first and second connection pipes are connected between the outdoor unit and the relay.

In an air-conditioning system according to the fifth embodiment of the present invention, a gas-liquid separator is provided at the middle portion of a first connection pipe or a second connection pipe that connects an outdoor unit with a plurality of indoor units, one side of each of the indoor units is connected to the first connection pipe or the second connection pipe, the other side is connected to the gas-liquid separator provided at either the first connection pipe or the second connection pipe by the third connection pipe, the gas-liquid separator and the first connection pipe or the second connection pipe provided with no gas-liquid separator are connected to a bypass pipe through an opening and closing unit and a flow rate controller, and a heat exchanging portion is provided in the bypass pipe to exchange heat between the gas-liquid separator of the third connection pipe and the flow rate controller.

In an air-conditioning system according to the sixth embodiment of the present invention, one side of the indoor units is switchedly connected with the first

or second connection pipe, the gas-liquid separator is provided at the middle portion of the first connection pipe connected to the outdoor heat exchanger, the third connection pipe is provided with the second flow rate controller and connects the first flow rate controller at the other side of the indoor units with the gas-liquid separator, the bypass pipe connects the gas-liquid separator with the second connection pipe and is provided with the heat-exchanging portion exchanging heat among the pipe path opening and closing unit, the third flow rate controller, and the third connection pipe below the third flow rate controller, and the controller controls the opening degree of the second flow rate controller based on the operation mode of each of the indoor units and the refrigerant state of the connection pipe between the first and second flow rate controllers and at the same time controls opening and closing of the-pipe path opening and closing unit.

In the air-conditioning system of the present invention, room cooling and room heating are selectively or simultaneously performed in each indoor unit as will be described later.

In the case where room heating is principally performed in room cooling and room heating concurrent operation according to the first embodiment of the present invention, a gaseous refrigerant of high pressure is supplied from a second connection pipe to each room cooling indoor unit to perform heating. The refrigerant which has performed heating is partially supplied from a third connection pipe to the room cooling indoor unit to exchange heat (cooling) and to a first connection pipe. Meanwhile, the other refrigerant is supplied to the first connection pipe through a second flow rate controller of the third connection pipe and is joined with a refrigerant which has passed the room cooling indoor unit to return to an outdoor unit. In the case where room cooling is principally performed, a gas of high pressure is heat-exchanged in the outdoor heat exchanger and supplied to the indoor by the first connection pipe in a two-phase state.

Some of the refrigerant is supplied to the room heating indoor unit and then to the third connection pipe which is not heated. Meanwhile, the other refrigerant is supplied to the third connection pipe and is joined with the refrigerant from the room heating indoor unit through the second flow rate controller so that it may be supplied to each room cooling indoor unit. The refrigerant supplied to the room cooling indoor unit is heat-exchanged (cooled) and then is guided to the outdoor unit through the second connection pipe to return to the compressor. In case of room heating, the refrigerant is supplied from the outdoor unit to each indoor unit

through the second connection pipe.

The refrigerant is heat-exchanged (heated) and returns to the outdoor unit through the third connection pipe. In case of room cooling only, the refrigerant is supplied to each indoor unit through the first connection pipe and the third connection pipe and is heat-exchanged (cooled). Then, the refrigerant returns to the outdoor unit through the second connection pipe. Furthermore, in the case where room heating is principally performed in room cooling and room heating concurrent operation, a refrigerant state signal of the third connection pipe extending from the first flow controller to the second flow rate controller is input to the controller. The controller outputs a signal for controlling an opening degree of the flow rate controller so that the input refrigerant state signal may be supercooled within a predetermined range. In the case where room cooling is principally performed, the controller inputs an opening degree signal of the respective first and second flow rate controllers and outputs an opening degree control signal to the flow rate controller of the third connection pipe so that the opening degree may be within a predetermined range. In case of room cooling and room heating concurrent operation, the controller inputs an operation mode signal of the indoor unit and outputs a signal for fully making the opening degree of the second flow rate controller.

The controller according to the second embodiment of the present invention detects the operation mode of each indoor unit and the difference between a set temperature of each indoor unit and each room temperature and determines room heating, room cooling, room heating principally performed in room cooling and room heating concurrent operation, or room cooling principally performed in room cooling and room heating concurrent operation depending on the detected data.

In the room heating and room cooling concurrent operation, the volume of the compressor is controlled by the difference between the set temperature of each indoor unit and the room temperature and heat exchanging capacity of the outdoor heat exchanger is controlled to the maximum range. Further, in the case where the room heating is principally performed, the volume of the compressor is controlled by the difference between the set temperature of the room heating indoor unit and its room temperature and heat exchanging capacity of the outdoor heat exchanger is controlled by the difference between the set temperature of the room cooling indoor unit and its room temperature.

Further, in the case where room cooling is principally performed in room

cooling and room heating concurrent operation, the volume of the compressor is controlled by the difference between the set temperature of the room cooling indoor unit and its room temperature and heat exchanging capacity of the outdoor heat exchanger is controlled by the difference between the set temperature of the room heating indoor unit and its room temperature. Therefore, in the case where room heating is principally performed in room cooling and room heating concurrent operation, a gaseous refrigerant of high pressure is supplied from the second connection pipe to each room heating indoor unit to perform heating.

The refrigerant which has performed heating is partially supplied from the third connection pipe to the room cooling indoor unit to exchange heat (cooling) and to the first connection pipe.

Meanwhile, the other refrigerant is supplied to the first connection pipe through the second flow rate controller of the third connection pipe and is joined with the refrigerant which has passed the room cooling indoor unit to return to the indoor unit. In the case where room cooling is principally performed, a gas of high pressure is heat-exchanged in the outdoor heat exchanger and supplied to the indoor unit by the first connection pipe in a two-phase state.

Some of the refrigerant is supplied to the room heating indoor unit to perform heating and then to the third connection pipe.

Meanwhile, the other refrigerant is supplied to the third connection pipe and is joined with the refrigerant from the room heating indoor unit through the second flow rate controller so that it may be supplied to each room cooling indoor unit.

The refrigerant supplied to the room cooling indoor unit is heat-exchanged (cooled) and then is guided to the outdoor unit through the second connection pipe to return to the compressor.

In case of room heating only, the refrigerant is supplied from the outdoor unit to each indoor unit through the second connection pipe.

The refrigerant is heat-exchanged (heated) and returns to the outdoor unit through the third connection pipe.

In case of room cooling only, the refrigerant is supplied to each indoor unit through the first connection pipe and the third connection pipe and is heat-exchanged (cooled). Then, the refrigerant returns to the outdoor unit through the second connection pipe.

In the air-conditioning system according to the third embodiment of the present invention, in the case where room heating is principally performed in room

cooling and room heating concurrent operation, the gaseous refrigerant of high pressure is supplied from the second connection pipe to each room heating indoor unit to perform heating.

The refrigerant which has performed heating is partially supplied from the third connection pipe to the room cooling indoor unit to exchange heat (cooling) and to the first connection pipe.

Meanwhile, the other refrigerant is supplied to the first connection pipe through the flow rate controller of the third connection pipe and is joined with the refrigerant which has passed the room cooling indoor unit to return to the indoor unit.

In the case where room cooling is principally performed in room cooling and room heating concurrent operation, a gas of high pressure is heat-exchanged in the outdoor heat exchanger and supplied from the first connection pipe to the gas-liquid separator in a two-phase state. After the gas is separated into gas and liquid by the gas-liquid separator, it is supplied to the room heating indoor unit to perform heating and then to the third connection pipe.

Meanwhile, the other liquid phase refrigerant is supplied to the third connection pipe and is joined with the refrigerant from the room heating indoor unit through a receiver and a flow rate controller to be supplied to the room cooling indoor unit.

The refrigerant supplied to the room cooling indoor unit is heat-exchanged (cooled) and then is guided to the outdoor unit through the second connection pipe to return to the compressor.

In case of room heating only, the refrigerant is supplied from the outdoor unit to each indoor unit through the second connection pipe.

The refrigerant is heat-exchanged (heated) and returns to the outdoor unit through the third connection pipe. Further, in case of room cooling only, the refrigerant is supplied to each indoor unit through the first connection pipe and the third connection pipe and is heat-exchanged (cooled).

Then, the refrigerant returns to the outdoor unit through the second connection pipe. In the air-conditioning system according to the fourth embodiment of the present invention, in the case where room heating is principally performed in room cooling and room heating concurrent operation, the gaseous refrigerant of high pressure is supplied from the first connection pipe and the first branch joint to each indoor unit to perform heating. The refrigerant is then partially supplied from

the second branch joint to the indoor unit to perform cooling and then from the first branch joint to the second connection pipe.

Meanwhile, the other refrigerant is supplied to the second connection pipe through the second flow rate controller and is joined with the refrigerant which has passed the room cooling indoor unit to return to the outdoor unit.

In the case where room cooling is principally performed in room cooling and room heating concurrent operation, a gas of high pressure is heat-exchanged in the outdoor heat exchanger and supplied from the second connection pipe to the indoor unit in a two-phase state through the first branch joint to perform heating. Then, the gas is supplied to the second branch joint.

Meanwhile, the other refrigerant is joined with the refrigerant from the room heating indoor unit at the second branch joint and is supplied to each indoor unit through the second flow rate controller to perform cooling. Afterwards, the refrigerant is guided from the first branch joint to the outdoor unit through the first connection pipe to return to the compressor.

In case of room heating only, the refrigerant is supplied from the outdoor unit to each indoor unit through the first connection pipe and the first branch joint to perform heating. Then, the refrigerant returns from the second branch joint to the outdoor unit through the second connection pipe.

In case of room cooling only, the refrigerant is supplied from the outdoor unit to each indoor unit through the second connection pipe and the second branch joint to perform cooling. Then, the refrigerant returns from the first branch joint to the outdoor unit through the first connection pipe.

In the air-conditioning system according to the fifth embodiment of the present invention, in the case where room heating is principally performed in room cooling and room heating concurrent operation, the gaseous refrigerant of high pressure is supplied from the second connection pipe to each room heating indoor unit to perform heating.

The refrigerant which has performed heating is partially supplied from the third connection pipe to the room cooling indoor unit to perform heat exchange (cooling) and to the first connection pipe.

Meanwhile, the other refrigerant is supplied to the first connection pipe through the flow rate controller of the third connection pipe and is joined with the refrigerant which has passed the room cooling indoor unit to return to the outdoor unit.

In the case where room cooling is principally performed in room cooling and room heating concurrent operation, a gas of high pressure is heat-exchanged in the outdoor heat exchanger and supplied from the first connection pipe to the gas-liquid separator in a two-phase state. After the gas is divided into gas and liquid by the gas-liquid separator, it is supplied to the room heating indoor unit to perform heating and then to the third connection pipe.

Further, the other liquid phase refrigerant is supplied to the bypass pipe and the third connection pipe. The refrigerant supplied to the bypass pipe passes through an electronic valve and a capillary tube and is heat-exchanged with the refrigerant supplied to the third connection pipe in the heat exchanger. The refrigerant is then supplied to the second connection pipe.

Meanwhile, the refrigerant supplied to the third connection pipe is joined with the refrigerant from the room heating indoor unit through the second flow rate controller to return to each room cooling indoor unit.

The refrigerant supplied to the room cooling indoor unit is heat-exchanged (cooled) and then is guided to the outdoor unit through the second connection pipe to return to the compressor.

In case of room heating only, the refrigerant is supplied from the outdoor unit to each indoor unit through the second connection pipe.

The refrigerant is heat-exchanged (heated) and returns to the outdoor unit through the third connection pipe. Further, in case of room cooling only, the refrigerant is supplied to each indoor unit through the first connection pipe and the third connection pipe and is heat-exchanged (cooled).

Then, the refrigerant returns to the outdoor unit through the second connection pipe.

In the case where room heating is principally performed in room cooling and room heating concurrent operation according to the sixth embodiment of the present invention, the gaseous refrigerant of high pressure is supplied from the second connection pipe to each indoor unit to perform heating.

The refrigerant is then partially supplied from the third connection pipe to the room cooling indoor unit to perform heat exchange (cooling) and then supplied to the first connection pipe.

Meanwhile, the other refrigerant is supplied to the first connection pipe through the second flow rate controller of the third connection pipe and is joined with the refrigerant which has passed the room cooling indoor unit, to return to the

outdoor unit.

Further, a refrigerant state signal of the third connection pipe extending from the first flow controller to the second flow rate controller is input to the controller. The controller controls an opening degree of the second flow rate controller so that the input refrigerant state signal may be supercooled within a predetermined range. Additionally, in the case where room heating is principally performed, the controller controls a pipe path switch to be fully opened.

In the case where room cooling is principally performed in room cooling and room heating concurrent operation, a gas of high pressure is heat-exchanged in the outdoor heat exchanger and supplied from the first connection pipe to the gas-liquid separator in a two-phase state.

After the gas is divided into gas and liquid by the gas-liquid separator, it is supplied to the room heating indoor unit to perform heating and then to the third connection pipe.

Further, the other liquid phase refrigerant is supplied to the bypass pipe and the third connection pipe. The refrigerant supplied to the bypass pipe passes through a pipe path switch and the third flow rate controller and is heat-exchanged with the refrigerant supplied to the third connection pipe in the heat exchanger. The refrigerant is then supplied to the second connection pipe.

Meanwhile, the refrigerant supplied to the third connection pipe is joined with the refrigerant from the room heating indoor unit through the second flow rate controller to return to each room cooling indoor unit.

The refrigerant supplied to the room cooling indoor unit is heat-exchanged (cooled) and then is guided to the outdoor unit through the second connection pipe to return to the compressor.

Further, the refrigerant state signal of the third connection pipe extending from the first flow controller to the second flow rate controller is input to the controller. The controller controls the opening degree of the second flow rate controller so that the input refrigerant state signal may be supercooled within a predetermined range.

Additionally, in the case where room cooling is principally performed, the controller controls the pipe path switch to be fully opened. In case of room heating only, the refrigerant is supplied from the outdoor unit to each indoor unit through the second connection pipe.

The refrigerant is heat-exchanged (heated) to return to the outdoor unit

through the third connection pipe. At this time, the controller controls the second flow rate controller to be fully opened and controls the pipe path switch to be fully closed.

Further, in case of room cooling only, the refrigerant is supplied to each indoor unit through the first connection pipe and the third connection pipe and then is heat-exchanged.

Then, the refrigerant returns to the outdoor unit through the second connection pipe.

At this time, the controller controls the second flow rate controller to be fully opened and controls the pipe path switch to be fully opened.

Hereinafter, the preferred embodiments of the present invention will be described with reference to the drawings.

FIG. 1 is a schematic diagram showing the entire structure the refrigerant system of the air-conditioning system according to the first embodiment of the present invention. FIG. 2 is a schematic diagram showing the operation wherein either only room cooling or only room heating is carried out in the first embodiment of FIG. 1. FIG. 2 to FIG. 4 illustrate the operation of room cooling and room heating according to the embodiment of FIG. 1. FIG. 2 illustrates room cooling or room heating. FIG. 3 and FIG. 4 illustrate room cooling and room heating concurrent operation. FIG. 3 illustrates the case where room heating is principally performed (room heating operation capacity is greater than room cooling operation capacity), and FIG. 4 illustrates the case where room cooling is principally performed (room cooling operation capacity is greater room heating operation capacity).

Since the same reference numerals will be used throughout the drawings to refer to the same or like parts, repeated description will be omitted.

In this embodiment, although three indoor units are connected with an outdoor unit in the same manner as the related art, two or more indoor units may be connected with an outdoor unit in the same method.

In addition, although an outdoor unit 1 of an air-conditioning system includes a compressor 2, a four-way valve 3, an outdoor heat exchanger 4, and an accumulator 8, the outdoor heat exchanger 4 and the four-way valve 3 are shown in the drawings for convenience.

In the drawings, a reference numeral 20 represents a three-way switching valve that connects one side of an indoor heat exchanger 10 to a first connection

pipe 13 and a second connection pipe 14. A reference numeral 21 represents a first electric expansion valve, which is a first flow rate controller, connected to the other side of the indoor heat exchanger 10.

Indoor units 9a to 9c are comprised of the three-way switching valve 20, the indoor heat exchanger 10, and the first electric expansion valve 21.

A reference numeral 22 represents a third connection pipe connected to the first electric expansion valve 212 of each indoor unit and also connected to the first connection pipe 13 through a second electric expansion valve 23, which is a second flow rate controller, provided at a pipe path.

The operation of the aforementioned air-conditioning system according to the first embodiment of the present invention will be described.

First, room heating operation will be described with reference to FIG. 2. A solid line arrow represents a flow of a refrigerant.

A refrigerant gas of high temperature and high pressure discharged from the compressor 2 is guided from the outdoor to the indoor by the second connection pipe 14. The refrigerant gas is supplied to the indoor heat exchanger 10 through the three-way switching valve 20 of the respective indoor units 9a to 9c. The heat-exchanged (heated) refrigerant is condensedly liquefied.

The liquefied refrigerant is supplied to the third connection pipe 22 through the first electric expansion valve 21 and passes through the electric expansion valve 23. The refrigerant is depressurized to become a two-phase state of low pressure at either first electric expansion valve 21 or the second electric expansion valve 23.

The depressurized refrigerant is supplied to the outdoor heat exchanger 4 of the outdoor unit 1 through the first connection pipe 13. The refrigerant is heat-exchanged in the outdoor heat exchanger 4 and then is inhaled to the compressor 2 in a gas state.

In this way, the circulation cycle is formed to carry out the room heating operation.

Next, room cooling operation will be described with reference to FIG. 2. A dashed line arrow represents a flow of a refrigerant.

A refrigerant gas of high temperature and high pressure discharged from the compressor 2 is heat-exchanged in the outdoor heat exchanger 4 and then condensedly liquefied. The refrigerant is supplied to the respective indoor units 9a to 9c through the first connection pipe 13 and the third connection pipe 22.

The refrigerant supplied to the respective indoor units 9a to 9c is

depressurized at low pressure by the first electric expansion valve 21. The refrigerant is then supplied to the indoor heat exchanger 10 and heat-exchanged (cooled) with indoor air to evaporate in a gas state.

The refrigerant of the gas state is inhaled to the compressor through the second connection pipe 14 by the three-way switching valve 20. In this way, the circulation cycle is formed to carry out the room cooling operation.

Next, the case where room heating is principally performed in room cooling and room heating concurrent operation will be described with reference to FIG. 3. An arrow represents a flow of a refrigerant.

A refrigerant discharged from the compressor 2 is supplied from the second connection pipe 14 to the respective indoor units 9b and 9c through the three-way switching valve 20. The refrigerant is heat-exchanged (heated) in the indoor heat exchanger 10. The heat-exchanged refrigerant is condensedly liquefied.

The liquefied refrigerant is supplied to the third connection pipe 22 through the first electric expansion valve 21 of a fully opened state.

Some of the refrigerant is supplied to the indoor unit 9a and is depressurized by the first expansion valve 21. Then, the refrigerant is supplied to the indoor heat exchanger 10 and then is heat-exchanged (cooled) in the indoor heat exchanger 10 to evaporate in a gas state. The refrigerant of the gas state is supplied to the first connection pipe 13 through the three-way switching valve 20.

Meanwhile, the other refrigerant is depressurized at low pressure by the second electric expansion valve 23. Then, the refrigerant is supplied from the third connection pipe 22 to the first connection pipe 13 and then is joined with the refrigerant from the room cooling indoor unit 9a. The refrigerant is heat-exchanged in the outdoor heat exchanger 4 to evaporate in a gas state. Finally, the refrigerant returns to the compressor. In this way, the circulation cycle is formed to carry out the case where room heating is principally performed.

Further, the case where room cooling is principally performed in room cooling and room heating concurrent operation will be described with reference to FIG. 4.

A refrigerant discharged from the compressor 2 is supplied to the outdoor heat exchanger 4. The refrigerant is heat-exchanged in the outdoor heat exchanger 4 to become a two-phase of high temperature and high pressure. The refrigerant is supplied to the indoor by the first connection pipe 13.

Some of the refrigerant is supplied to the indoor heat exchanger 10 of the

indoor unit 9a through the three-way switching valve 20. Then, the refrigerant is heat-exchanged (heated) in the indoor heat exchanger 10 and then condensedly liquefied. The liquefied refrigerant is supplied from the first electric expansion valve 21 to the third connection pipe 22.

Meanwhile, the other refrigerant is joined with the refrigerant from the room heating indoor unit 9a through the second electric expansion valve 23 (fully opened state) of the third connection pipe 22.

The refrigerant is supplied from the third connection pipe 22 to the respective indoor units 9b and 9c and is depressurized at low pressure by the first electric expansion valve 21. The refrigerant is then supplied to the indoor heat exchanger 10 and heat-exchanged (cooled) to evaporate in a gas state.

Finally, the refrigerant of the gas state is supplied to the second connection pipe 14 through the three-way switching valve 20 to return to the compressor 2. In this way, the circulation cycle is formed to carry out the case where room cooling is principally performed.

FIG. 5 is a schematic diagram showing the entire structure of the refrigerant system of the modified air-conditioning system according to the first embodiment of the present invention. FIG. 6 to FIG. 8 illustrate the operation of room cooling and room heating according to the embodiment of FIG. 5. FIG. 6 illustrates room cooling or room heating. FIG. 7 and FIG. 8 illustrate room cooling and room heating concurrent operation. FIG. 7 illustrates the case where room heating is principally performed, and FIG. 8 illustrates the case where room cooling is principally performed.

In this embodiment, three indoor units are connected with an outdoor unit.

In the drawings, reference numerals 30a to 30c represent indoor unit operation controllers, which output a signal for controlling a valve opening degree to the first electric expansion valve 21 and output operation mode signals for the indoor units to a controller which will be described later.

Reference numerals 31 and 32 respectively represent a temperature sensor, such as a thermistor, and a pressure sensor, such as an electric pressure converter. The temperature sensor 31 and the pressure sensor 32 are provided at the third connection pipe 22 between the first electric expansion valve 21 and the second electric expansion valve 23. A reference numeral 33 represents a controller that inputs signals from the indoor unit operation controllers 30a to 30c, the temperature sensor 31 and the pressure sensor 32 and outputs a signal for controlling an opening

degree of the second electric expansion valve 23.

FIG. 9 is a flow chart illustrating a control flow of the controller according to the embodiment of FIG. 5.

In the drawing, X_{V2} and X_{V2*} respectively represent a present command value for the opening degree and a new command value for the opening degree in the second electric expansion valve 23. $\triangle X_{V2}$ represents a variation of the above values.

X_{VIH} and X_{VIC} respectively represent a maximum valve opening degree of the room heating indoor unit and a maximum valve opening degree of the room cooling indoor unit in the first electric expansion valve 21. X_{Hmax} and X_{cmax} respectively represent a maximum control valve opening degree of the room heating indoor unit and a maximum control valve opening degree of the room cooling indoor unit. SC represents a supercooling degree of the refrigerant at a portion where the temperature sensor 31 and the pressure sensor 32 are provided. SC_H and SC_L respectively represent an upper limit and a lower limit of the supercooling degree.

Subsequently, the operation of the air-conditioning system according to the embodiment of FIG. 5 will be described.

First, room heating operation will be described with reference to FIG. 2.

A refrigerant gas of high temperature and high pressure discharged from the compressor 2 is guided from the outdoor to the indoor by the second connection pipe 14. The refrigerant gas is supplied to the indoor heat exchanger 10 through the three-way switching valve 20 of the respective indoor units 9a to 9c. The heat-exchanged (heated) refrigerant is condensedly liquefied.

In this case, a flow rate of the refrigerant supplied to the respective indoor units 9a to 9c is controlled by the first electric expansion valve 21 so that the refrigerant of the indoor heat exchanger may slightly be supercooled to become a liquid state.

The refrigerant of the liquid state is depressurized at low pressure by the first electric expansion valve 21. The refrigerant is then supplied to the third connection pipe.

Meanwhile, the controller 33 inputs the operation mode signal of each indoor unit from the indoor unit operation controllers 30a to 30c and outputs a signal for fully making the opening degree of the second electric expansion valve 23 as shown in FIG. 9 after detecting that all the indoor units are in a heating operation mode.

The refrigerant supplied to the third connection pipe 22 is supplied to the outdoor heat exchanger 4 of the outdoor unit 1 through the first connection pipe 13 by the second electric expansion valve 23. The refrigerant is heat-exchanged in the outdoor heat exchanger 4 to evaporate in a gas state and then inhaled to the compressor 2. In this way, the circulation cycle is formed to carry out the room heating operation.

Next, room cooling operation will be described with reference to FIG. 6.

A refrigerant gas of high temperature and high pressure discharged from the compressor 2 is condensedly liquefied in the outdoor heat exchanger 4. The refrigerant is then supplied to the respective indoor units 9a to 9c through the first connection pipe 13 and the third connection pipe 22.

At this time, the opening degree of the second electric expansion valve 23 provided at the middle portion of the third connection pipe 22 becomes full because the controller 33 outputs a signal for fully making the opening degree of the second electric expansion valve 23 to the second electric expansion valve 23 as shown in FIG. 9 after inputting the operation mode signal of each indoor unit from the operation controllers 30a to 30c and detecting that all the indoor units are in a heating operation mode. The refrigerant passes through the opening of the second electric expansion valve 23 without any change. The refrigerant supplied to the respective indoor units 9a to 9c is depressurized at low pressure by the first electric expansion valve 21. The refrigerant is then supplied to the indoor heat exchanger 10. Then, the refrigerant is heat-exchanged (cooled) with indoor air to evaporate in a gas state.

The refrigerant of the gas state is inhaled to the compressor 2 through the second connection pipe 14 by the three-way switching valve 20. In this way, the circulation cycle is formed to carry out the room cooling operation.

Further, the case where room heating is principally performed in room cooling and room heating concurrent operation will be described with reference to FIG. 7 and FIG. 9.

First, a refrigerant discharged from the compressor 2 is supplied from the second connection pipe 14 to the respective indoor units 9b and 9c through the three-way switching valve 20. The refrigerant is heat-exchanged (heated) in the indoor heat exchanger 10. The heat-exchanged refrigerant is condensedly liquefied.

In this case, a flow rate of the refrigerant supplied to the respective indoor units 9b and 9c is controlled by the first electric expansion valve 21 so that the

refrigerant of the indoor heat exchanger may slightly be supercooled to become a liquid state.

The liquefied refrigerant is depressurized at middle pressure by the first electric expansion valve 21. The refrigerant of the middle pressure is then supplied to the third connection pipe 22.

Some of the refrigerant supplied to the third connection pipe 22 is supplied to the room cooling indoor unit 9a, and the refrigerant is again depressurized at low pressure by the first expansion valve 21. Then, the refrigerant is supplied to the indoor heat exchanger 10 and then is heat-exchanged (cooled) in the indoor heat exchanger 10 to evaporate in a slightly supercooled gas state. The refrigerant of the gas state is supplied to the first connection pipe 13 through the three-way switching valve 20.

Meanwhile, the other refrigerant is depressurized at low pressure by the second electric expansion valve 23. Then, the refrigerant is supplied from the third connection pipe 22 to the first connection pipe 13 and then is joined with the refrigerant from the room cooling indoor unit 9a. The refrigerant is heat-exchanged in the outdoor heat exchanger 4 to evaporate in a gas state. Finally, the refrigerant returns to the compressor. In this way, the circulation cycle is formed to carry out the case where room heating is principally performed.

The operation of the second electric expansion valve 23 during the case where room heating is principally performed will be described with reference to FIG. 9.

The controller 33 inputs the operation mode signals from the indoor unit operation controllers 30a to 30c and the signals of the temperature sensor 31 and the pressure sensor 32 provided at the third connection pipe 22.

After detecting the room heating operation mode from the input signals, the controller 33 operates the supercooling degree SC of the refrigerant liquid supplied to the third connection pipe 22 using the signals of the temperature sensor 31 and the pressure sensor 32.

Furthermore, the controller 33 determines whether the supercooling degree SC is within the range of the control supercooling degrees SC_L to SC_H. When the supercooling degree SC is within the range of the control supercooling degrees SC_L to SC_H, the controller 33 outputs a command value X_{V2} of the valve opening degree to the second electric expansion valve 23 as a new command value X_{V2*} of the valve opening degree.

When the supercooling degree SC is not within the range of the control supercooling degrees SC_L to SC_H and is greater than the upper limit SC_H of the control supercooling degree, the controller 33 outputs a command value of the valve opening degree, which is obtained by adding a variation $\triangle X_{V2}$ of the valve opening degree to the present command value X_{V2} of the valve opening degree, to the second electric expansion valve 23 as a new command value of the valve opening degree. When the supercooling degree SC is smaller than the lower limit SC_L of the control supercooling degree, the controller 33 outputs a command value of the valve opening degree, which is obtained by subtracting the variation $\triangle X_{V2}$ from the command value X_{V2}, to the second electric expansion valve 23 as a new command value X_{V2*} of the valve opening degree.

The opening degree of the second electric expansion valve 23 is controlled as above, and the supercooling degree of the refrigerant liquid is maintained within a predetermined range at the portion where the temperature sensor 31 and the pressure sensor 32 of the third connection pipe 22 are provided.

Further, the control supercooling degree is set as a value smaller than the control supercooling degree of the first electric expansion valve 21 corresponding to the room heating indoor units 9b and 9c.

Next, in the case where room cooling is principally performed, as shown in FIG. 8, a refrigerant discharged from the compressor 2 is supplied to the outdoor heat exchanger 4. The refrigerant is heat-exchanged in the outdoor heat exchanger 4. The heat-exchanged refrigerant is supplied to the indoor through the first connection pipe 13 in a two-phase refrigerant of high temperature and high pressure.

Some of the refrigerant is supplied to the indoor heat exchanger 10 of the room heating indoor unit 9a through the three-way switching valve 20. The refrigerant is then heat-exchanged (heated) and condensedly liquefied. The liquefied refrigerant is depressurized at middle pressure by the first electric expansion valve 21. The refrigerant of the middle pressure is then supplied to the third connection pipe 22.

At this time, a flow rate of the refrigerant supplied to the room heating indoor unit 9a is controlled under the control of the opening degree of the first electric expansion valve 21, so that the refrigerant at the inlet of the indoor heat exchanger may slightly be supercooled to become a liquid state.

Meanwhile, a flow rate of the other refrigerant is controlled by the second electric expansion valve 23 of the third connection pipe 22. The other refrigerant is

depressurized at the middle pressure. The refrigerant of the middle pressure is joined with the refrigerant from the room heating indoor unit 9a.

The refrigerant is supplied from the third connection pipe 22 to the room cooling indoor units 9b and 9c, and the refrigerant is again depressurized at low pressure by the first expansion valve 21. Then, the refrigerant is supplied to the indoor heat exchanger 10 and then is heat-exchanged (cooled) in the indoor heat exchanger 10 to evaporate in a gas state.

In this case, the flow rate of the refrigerant supplied to the room cooling indoor units 9b and 9c is controlled under the control of the valve opening degree of the first electric expansion valve 21 so that the refrigerant at the outlet of the indoor heat exchanger may become a slightly supercooled gas state.

The refrigerant of the gas state is supplied to the second connection pipe 14 through the three-way switching valve 20 and then is inhaled to the compressor 2. In this way, the circulation cycle is formed to carry out the case where room cooling is principally performed.

The operation of the second electric expansion valve 23 during the case where room cooling is principally performed will be described with reference to FIG. 9 in the same manner as the case where room heating is principally performed.

First, a control of the second electric expansion valve 23 will be described. In a circuit of the refrigerant, since the first electric expansion valve 21 of the room heating indoor unit 9a and the first electric expansion valve 21 of the room cooling indoor units 9ba and 9c are provided in series in a flow of the refrigerant. The middle pressure occurs at the outlet of the first electric expansion valve 21 of the room heating indoor unit 9a and the inlet of the first electric expansion valve 21 of the room cooling indoor units 9b and 9c to obtain a required refrigerant flow rate. It is necessary to ensure pressure difference before and after the first electric expansion valve 21.

The second electric expansion valve 23 serves to control the middle pressure. The controller 33 controls the middle pressure by shifting the refrigerant flow rate that bypasses the room heating indoor unit 9a at the second electric expansion valve 23 so that the first electric expansion valve 21 of the room heating indoor unit 9a and the room cooling indoor units 9b and 9c may obtain the required refrigerant flow rate within a predetermined range of the valve opening degree.

The controller 33 inputs the operation mode signals from the indoor unit operation controllers 33a to 33c and the valve opening signals X_{VIH} and X_{VIC} of the

first electric expansion valve 21 in the same manner as the case where room heating is principally performed.

After detecting the room cooling operation mode from the input signals, the controller 33 compares the valve opening signal X_{VIH} of the first electric expansion valve 21 of the room heating indoor unit 9a with the maximum valve opening signal X_{HMAX} for heating control. As a result, if the valve opening signal X_{VIH} is greater than the maximum valve opening signal X_{HMAX}, the controller 33 outputs a value X_{V2*}, which is obtained by subtracting the variation $\triangle X_{V2}$ of the valve opening degree from the present command value X_{V2} of the valve opening degree, to the second electric expansion valve 23 as a new command value of the valve opening degree.

If the valve opening signal X_{VIH} is smaller than the maximum valve opening signal X_{HMAX}, the controller 33 compares the opening signal X_{VIC} of the first electric expansion valve 21 of the room cooling indoor units 9b and 9c with the maximum valve opening signal X_{CMAX} for cooling control.

As a result, if the opening signal X_{VIC} is greater than the maximum valve opening signal X_{CMAX}, the controller 33 outputs a value X_{V2*}, which is obtained by adding the variation $\triangle X_{V2}$ to the present command value X_{V2} of the valve opening degree, to the second electric expansion valve 23 as a new command value of the valve opening degree.

If the valve opening signal X_{VIC} is smaller than the maximum valve opening signal X_{CMAX}, the controller 33 outputs the present command value X_{V2} to the second electric expansion valve 23 as a new command value X_{V2*} of the valve opening degree.

In the above embodiment, the controller has been designed to input the operation mode signals from the indoor unit operation controllers 33a to 33c, the valve opening signal of the first electric expansion valve 21, the temperature signal from the temperature sensor 31, and the pressure signal from the pressure sensor 32. However, the controller is not limited to such case.

In the above embodiment, it has been described that the indoor units have the same capacity. However, the indoor units may have different capacity, respectively. In this case, a capacity signal of each indoor unit is input to the controller 33 to detect room cooling and room heating operation capacity of the indoor unit, thereby detecting an operation mode. Alternatively, an operation mode signal of the outdoor unit is input to detect an operation mode. Therefore, the

operation mode can exactly be recognized and optimal control can be performed.

Further, in the above embodiment, the three-way switching valve 20 is provided to be switchedly connected with the first connection pipe 13 and the second connection pipe 14. However, in the same manner as the scheme illustrating a refrigerant system of a modified air-conditioning system shown in FIG. 10, switching valves of two electronic valves 40 and 41 may be provided to be switchedly connected with the first connection pipe 13 and the second connection pipe 14.

Further, in the above embodiment, it has been described that the first electric expansion valve 21 is provided in the indoor units 9a to 9c. However, as shown in FIG. 10, a temperature expansion valve 12, a capillary tube 42, and a check valve 11 may be provided in the indoor units. In case of the room cooling indoor unit, the refrigerant is depressurized at low pressure by the temperature expansion valve 12. In case of the room heating indoor unit, the refrigerant is supplied to the third connection pipe 22 from the indoor heat exchanger 10 through the capillary tube 42 and the check valve 11.

Although the third connection pipe 22 is provided with the second electric expansion valve 23 in the first and second embodiments, the second electric expansion valve can be replaced by e.g. a switching valve of an electric flow control valve (ball valve etc.) 43 as shown in FIG. 10.

Although the indoor units 9a-9c are constituted by the three-way switching valve 20, the indoor heat exchanger 10, and the first electric expansion valves 21 in the above embodiments, each indoor unit 9a, 9b or 9c may be constituted by either only the indoor heat exchanger 10, or the combination of the indoor heat exchanger 10 and the three-way switching valve 20 or the first electric expansion valve 21 so that the three-way switching valve 20 and the first electric expansion valve 21 can be controlled depending on the air conditions of the indoor unit.

In addition, the embodiments as stated earlier are explained in reference to the case wherein the outdoor heat exchanger 4 and the indoor heat exchanger 10 carry out heat exchanging between air and the refrigerant. Either the outdoor heat exchanger or the indoor heat exchanger, or both outdoor and indoor heat exchangers can carry out heat exchanging using water and the refrigerant.

Further, in the above embodiments, the gas-liquid separator may be provided at the middle portion of the first connection pipe. In this case, the refrigerant is heat-exchanged in the outdoor heat exchanger when room cooling is principally

performed under the room cooling and room heating concurrent operation. The refrigerant of two-phase state is separated by the gas-liquid separator. The refrigerant of the gas state is guided to the room heating indoor unit and the third connection pipe to improve heat efficiency. (The detailed description is disclosed in the specification of the Japanese Patent Application No. 63-260762 invented by the same applicant.)

A refrigerant system of an air-conditioning system according to the second embodiment of the present invention will be described. FIG. 11 is a schematic diagram showing the entire structure the refrigerant system of the air-conditioning system according to the second embodiment of the present invention. FIG. 12 to FIG. 14 illustrate the operation of room cooling and room heating according to the embodiment of FIG. 11. FIG. 12 illustrates room cooling or room heating. FIG. 13 and FIG. 14 illustrate room cooling and room heating concurrent operation. FIG. 13 illustrates the case where room heating is principally performed (room heating operation capacity is greater than room cooling operation capacity), and FIG. 14 illustrates the case where room cooling is principally performed (room cooling operation capacity is greater room heating operation capacity).

FIG. 15 is a flow chart illustrating a control flow of a controller. Since the same reference numerals as those of FIG. 1 will be used throughout the drawings to refer to the same or like parts, their repeated description will be omitted.

In the drawings, a reference numeral 1 represents an outdoor unit, The outdoor unit 1 includes a variable rotational frequency type compressor 2 as a volume control type of compressor such as an inverter, an outdoor heat exchanger 4 of a four-way valve 3, an outdoor fan 19 as a heat exchanging amount changing means for the outdoor heat exchanger 4, and an accumulator 8. However, the accumulator 8 will be omitted in the drawings for convenience.

In the drawings, reference numerals 30a to 30c represent indoor unit operation controllers, which output to the controller 33 as described in detail later the operation modes of the indoor units, and the difference between a set temperature and an actual room temperature concerning each indoor unit. The difference means that between a set temperature and the temperature of inhaled air because the temperature of the inhaled air is treated as actual room temperatures. A reference numeral 31 represents a temperature sensor such as a thermistor, which detects the temperature of the inhaled air in each indoor unit. Each of the indoor unit operation controllers 30a to 30c outputs the operation mode and the rated

capacity of each of the indoor units 9a to 9c, and the temperature difference between a set temperature and inhaled air temperature detected by each indoor unit, to the controller 33, which in turn outputs a signal for controlling the rotational frequency of the compressor 2 and RPM of the outdoor fan 19.

In this embodiment, the rotational frequency of the compressor 2 is adjusted to control the volume of the compressor 2, and the RPM of the outdoor fan 19 is adjusted to control heat exchanging amount.

In FIG. 15, $\triangle Tj$ represents the temperature difference $\triangle Tj=Tsetj-T_{Rj}$ between the set temperature Tsej and the inhaled air temperature T_{Rj}. In a "j"th indoor unit. MAX$\triangle$Tj and MIN$\triangle$Tj represent the greatest value and the smallest value, respectively, among the values of the temperature differences, $\triangle$Tj in all indoor units. MAX$\triangle Tj^{H}$ represents the greatest value among $\triangle$Tj of room heating indoor units under room cooling and room heating conpresent operation. MIN$\triangle Tj^{C}$ represents the smallest value among $\triangle$Tj of room cooling indoor units under room cooling and room heating conpresent operation. Symbol, α, represents a control target range of $\triangle$Tj, +α representing the upper limit and -α representing the lower limit.

In addition, symbols, f_{comp} and f_{comp}^{*} s represent the present command value and a new command value, respectively, with respect to the rotational frequency of the compressor 2, $\triangle f_{comp}$ representing a variation between the present command value and the new command value. Symbols, f_{fan} and f_{fan}^{*}, represent the present command value and a new command value, respectively, with respect to the revolution of the outdoor fan 19, $\triangle f_{fan}$ representing a variation between the present command value and the new command value. Symbol, MAXf_{fan} represents the maximum revolution of the outdoor fan 19.

The operation of the air conditioning system which is constructed in accordance with the fourth embodiment will be described.

Room heating operation will be described with reference to FIG. 12.

A refrigerant gas of high temperature and high pressure discharged from the compressor 2 is guided from the outdoor to the indoor by the second connection pipe 14. The refrigerant gas is supplied to the indoor heat exchanger 10 through the three-way switching valve 20 of the respective indoor units 9a to 9c. The heat-exchanged (heated) refrigerant is condensedly liquefied.

The liquefied refrigerant is supplied to the third connection pipe 22 through the first electric expansion valve 21. The refrigerant passes through the second

electric expansion valve 23. At this time, the refrigerant is depressurized at low pressure at the first electric expansion valve 21 or the second electric expansion valve 23 to become a two-phase state. The refrigerant is then supplied to the outdoor heat exchanger 4 of the outdoor unit 1 through the first connection pipe 13. The refrigerant is heat-exchanged in the outdoor heat exchanger 4 to become a gas state. The refrigerant is finally inhaled to the compressor 2.

In this way, the circulation cycle is formed to carry out the room heating operation. A solid line arrow represents the flow of the refrigerant in case of the room heating only. The control method on the rotational frequency of the compressor 2 and the revolution of the outdoor fan 19 on room heating only will be described with reference to FIGS. 15-1 and 15-2.

First, the controller 33 receives the operation mode from each indoor unit through the indoor unit operation controllers 30a to 30c. When all indoor units are on room heating, the controller 33 determines that it is now under room heating operation mode, and controls the compressor and the outdoor fan according to the control flow chart of FIG. 15-2.

Specifically, the controller 33 seeks the greatest value among $\triangle Tj$ of the room heating indoor units. When the greatest value is within a predetermined control target range, the controller 33 outputs the present command value f_{comp} of the rotational frequency of the compressor 2 as a new command value f^*_{comp} to the compressor 2. When the greatest value among $\triangle Tj$ of the room heating indoor units is greater than the upper limit $+\alpha$ of the control target range, the controller 33 determines that there is a unit short of capacity among the indoor units, and outputs a value, which is obtained by adding $\triangle f_{comp}$ to the present command value f_{comp} for the rotation frequency of the compressor 2, to the compressor 2 as a new command value f^*_{comp}.

When the greatest value among $\triangle Tj$ of the room heating indoor units is smaller than the lower limit $-\alpha$ of the control target range, the controller 33 determines that the capacity of each indoor unit is excessive, and outputs a value, which is obtained by subtracting $\triangle f_{comp}$ from the present command value f_{comp} for the rotational frequency of the compressor 2, to the compressor 2 as a new command value f^*_{comp}. Meanwhile, the outdoor fan 19 is controlled to rotate at the maximum revolution on room heating only.

Next, the operation on room cooling only will be described with reference to FIG. 12.

A refrigerant gas of high temperature and high pressure discharged from the compressor 2 is heat-exchanged and condensedly liquefied in the outdoor heat exchanger 4. The liquefied refrigerant is supplied to each of the indoor units 9a to 9c through the first connection pipe 13 and the third connection pipe 22.

The refrigerant supplied to the indoor units 9a to 9c is depressurized at low pressure by the first electric expansion valve 21. The refrigerant is then supplied to the indoor heat exchanger 10 and heat-exchanged (cooled) with room air to evaporate in a gas state.

The refrigerant of the gas state is finally inhaled to the compressor 2 through the second connection pipe 14 by the three-way switching valve 20. In this way, the circulation cycle is formed to carry out the room cooling operation. A dashed line arrow represents the flow of the refrigerant in case of the room cooling.

The control method on the rotational frequency of the compressor 2 and the revolution of the outdoor fan 19 on room cooling only will be described with reference to FIG. 15-1 and FIG. 15-2.

First, the controller 33 receives the operation mode of each indoor unit through the indoor unit operation controllers 30a to 30c. When all indoor units are on room cooling, the controller 33 determines that it is now under room cooling operation mode, and controls the compressor and the outdoor fan according to the control flow chart of FIG. 15-3.

Specifically, the controller 33 seeks the smallest value among $\triangle$Tj of room cooling indoor units. When the greatest value is within a predetermined control target range, the controller 33 outputs the present command value f_{comp} of the rotational frequency of the compressor 2 as a new command value f^*_{comp} to the compressor 2. When the smallest value among $\triangle$Tj of room cooling units is smaller than the lower limit $-\alpha$ of the control target range, the controller determines that there is an indoor unit short of capacity, and outputs a value, which is obtained by adding $\triangle f_{comp}$ to the present command value f_{comp} of the rotational frequency of the compressor 2, to the compressor 2 as a new command value f^*_{comp}. When the greatest value of $\triangle$Tj of the room cooling units is greater than the upper limit α of the control target range, the controller 33 determines that the capacity of all indoor unit is excessive, and outputs to the compressor 2 as a new command value f*.sub.comp a value which is obtained by subtracting $\triangle f_{comp}$ from the present command value f_{comp} of the rotational frequency of the compressor 2. Meanwhile, the outdoor fan 19 is controlled to rotate at the maximum revolution on room

cooling only.

Next, the case wherein room heating is principally performed under room cooling and room heating concurrent operation will be described with reference to FIG. 3.

First, the refrigerant discharged from the compressor 2 is supplied to each room heating indoor units 9b and 9c through the three-way switching valve 20 by the second connection pipe 14. The refrigerant is heat-exchanged (heated) in the indoor heat exchanger 10 and condensedly liquefied. The liquefied refrigerant is supplied to the third connection pipe 22 through the first electric expansion valve 21 which are fully opened. Some of the refrigerant is supplied to the indoor cooling unit 9a. The refrigerant is depressurized by the first electric expansion valve 21 and then is heat-exchanged (cooled) in the indoor heat exchanger 10 to evaporate in a gas state. The refrigerant is then supplied to the first connection pipe 13 through the three-way switching valve 20.

Meanwhile, the other refrigerant is depressurized at low pressure by the second electric expansion valve 23. Then, the refrigerant is supplied from the third connection pipe 22 to the first connection pipe 13 and is joined with the refrigerant from the indoor cooling unit 9a. The refrigerant is heat-exchanged in the outdoor heat exchanger 4 to evaporate in a gas state. Finally, the refrigerant returns to the compressor 2. In this way, the circulation cycle is formed to carry out the case where room heating is principally performed.

An arrow represents a flow of the refrigerant.

The control method on the rotational frequency of the compressor 2 and the revolution of the outdoor fan 19 will be described with reference to FIGS. 15-1 and 15-4.

The controller 33 receives the operation mode of each indoor unit through the indoor unit operation controllers 30a to 30c. When the controller 33 detects the concurrence of a room heating indoor unit and a room cooling indoor unit, the controller compares the total capacity required for room heating with the total capacity required for room cooling based on the number of room heating indoor units and the number of the room cooling indoor units.

When the total capacity required for room heating is greater than that required for room cooling, the controller 33 determines that it is now under the operation mode wherein room heating is principally performed. In accordance with the control flow chart of FIG. 15-4, the controller 33 controls the rotational

frequency of the compressor 2 so that the capacity of the room heating indoor units reaches a predetermined value, and controls the revolution of the outdoor fan 19 so that the capacity of the room cooling indoor units reaches a predetermined value.

In other words, the controller 33 seeks the greatest value $MAX\triangle Tj^H$ among $\triangle Tj$ of room heating indoor units. When the greatest value is within a predetermined control target range, the controller 33 outputs the present command value f_{comp} of the rotational frequency of the compressor 2 as a new command value f^*_{comp} to the compressor 2. When the greatest value $MAX\triangle Tj^H$ of $\triangle Tj$ of the room heating units is greater than the upper limit α of the control target range, the controller determines that there is an indoor unit short of capacity, and outputs a value, which is obtained by adding $\triangle f_{comp}$ to the present command value f_{comp} of the rotational frequency of the compressor 2, to the compressor 2 as a new command value f^*_{comp}. When the greatest value $MAX\triangle Tj^H$ of $\triangle Tj$ of the room heating units is smaller than the lower limit $-\alpha$ of the control target range, the controller determines that the capacity of all indoor unit is excessive, and outputs a value, which is obtained by subtracting $\triangle f_{comp}$ from the present command value f_{comp} of the rotational frequency of the compressor 2, to the compressor 2 as a new command value f^*_{comp}.

On the other hand, the revolution of the outdoor fan 19 is controlled based on the smallest value $MIN\triangle Tj^C$ among $\triangle Tj$ of room cooling indoor units.

Specifically, when the smallest value $MIN\triangle Tj^C$ among $\triangle Tj$ of the room cooling indoor units is within a predetermined control target range, the controller 33 outputs the present command value $\triangle f_{fan}$ of the revolution of the outdoor fan 19 to the outdoor fan 19 as a new command value f^*_{fan}.

When the smallest value $MIN\triangle Tj^C$ among $\triangle Tj$ of the room cooling indoor units is smaller than lower limit $-\alpha$ of the control target range, the controller determines that there is a unit short of capacity among the room cooling indoor units, and outputs a value, which is obtained by adding $\triangle f_{fan}$ to the present command value f_{fan} of the revolution of the outdoor fan 19, to the outdoor fan 19 as a new command value f^*_{fan}. When the smallest value $MIN\triangle Tj^C$ among $\triangle Tj$ of the room cooling indoor units is greater than the upper limit $+\alpha$ of the control target range, the controller 33 determines that the capacity of all room cooling indoor units is excessive, and outputs a value, which is obtained by subtracting $\triangle f_{fan}$ from the present command value f_{fan} of the revolution of the outdoor fan 19, to the outdoor fan 19 as a new command value f^*_{fan}.

Now, the case wherein room cooling is principally performed at under room cooling and room heating concurrent operation will be described with reference to FIG. 14.

The refrigerant discharged from the compressor 2 is supplied to the outdoor heat exchanger 4 and is heat-exchanged there to become a gas-liquid phase of high temperature and high pressure. The refrigerant is then supplied to the indoor by the first connection pipe 13.

Some of the refrigerant is supplied to the indoor heat exchanger 10 of the room heating indoor unit 9a through the three-way switching valve 20. The refrigerant is heat-exchanged (heated) in the indoor heat exchanger 10 and then condensedly liquefied. The liquefied refrigerant is supplied from the first electric expansion valve 21 to the third connection pipe 22.

Meanwhile, the other refrigerant is joined with the refrigerant from the room heating indoor unit 9a after passing through the second electric expansion valve 23 of the third connection pipe 22, which are fully opened.

The refrigerant is supplied from the third connection pipe 22 to each of the room cooling indoor units 9a and 9c. The refrigerant is depressurized at low pressure by the first electric expansion valve 21. Then, the refrigerant is supplied to the indoor heat exchanger 10 to evaporate in a gas state. The gaseous refrigerant is supplied to the second connection pipe through the three-way switching valve 20. Finally, the refrigerant returns to the compressor 2. In this way, the circulation cycle is formed to carry out the case where room cooling is principally performed. At this time, the control method on the rotational frequency of the compressor 2 and the revolution of the outdoor fan 19 will be described with reference to FIGS. 15-1 and 15-5.

The controller 33 receives the operation mode of each indoor unit through the indoor unit operation controllers 30a to 30c. When the controller 33 detects the concurrence of a room heating indoor unit and a room cooling indoor unit, it compares the total capacity required for room heating operation with the total capacity required for room cooling operation based on the number of the room heating units and the number of room cooling units.

When the total capacity required for room cooling is greater than that required for room heating, the controller 33 determines that it is now under the operation mode wherein room cooling is principally performed. And, in accordance with the flow chart of FIG. 15-5, the controller 33 controls the rotational frequency

of the compressor 2 so that the capacity of the room cooling units reaches a predetermined value, and controls the revolution of the outdoor fan 19 so that the capacity of the room heating units reaches a predetermined value.

In other words, the controller seeks the smallest value $MIN\triangle Tj^{C}$ among $\triangle Tj$ of room cooling indoor units. When the smallest value is within a predetermined control target range, the controller 33 outputs the present command value f_{comp} of the rotational frequency of the compressor 2 to the compressor 2 as a new command value f^{*}_{comp}. When the smallest value $MIN\triangle Tj^{C}$ of $\triangle Tj$ of the room cooling units is smaller than the lower limit $-\alpha$ of the control target range, the controller determines that there is an indoor unit short of capacity, and outputs a value, which is obtained by adding $\triangle f_{comp}$ to the present command value f_{comp} of the rotational frequency of the compressor 2, to the compressor 2 as a new command value f^{*}_{comp}.

When the smallest value $MIN\triangle Tj^{C}$ of $\triangle Tj$ of the room cooling units is greater than the upper limit α of the control target range, the controller determines that the capacity of all indoor unit is excessive, and outputs a value, which is obtained by subtracting $\triangle f_{comp}$ from the present command value f_{comp} of the rotational frequency of the compressor 2, to the compressor 2 as a new command value f^{*}_{comp}.

On the other hand, the revolution of the outdoor fan 19 is controlled based on the maximum value $MAX\triangle Tj^{H}$ among $\triangle Tj$ of room heating indoor units.

Specifically, when the greatest value $MAX\triangle Tj^{H}$ among $\triangle Tj$ of the room heating units is within a predetermined control target range, the controller 33 outputs the present command value f_{fan} of the revolution of the outdoor fan 19 to the outdoor fan 19 as a new command value f^{*}_{fan}.

When the greatest value $MAX\triangle Tj^{H}$ among $\triangle Tj$ of the room heating units is greater than upper limit $+\alpha$ of the control target range, the controller 33 determines that there is a unit short of capacity among the room heating units, and outputs a value, which is obtained by adding $\triangle f_{fan}$ to the present command value f_{fan} of the revolution of the outdoor fan 9, to the outdoor fan 19 as a new command value $\triangle f^{*}_{fan}$.

When the greatest value $MAX\triangle Tj^{H}$ among $\triangle Tj$ of the room heating units is smaller than the lower limit $-\alpha$ of the control target range, the controller 33 determines that the capacity of all room heating units is excessive, and outputs a value, which is obtained by subtracting $\triangle f_{fan}$ from the present command value f_{fan} of the revolution of the outdoor fan 9, to the outdoor fan 19 as a new command

value $\triangle f^*_{fan}$.

Although in the above embodiment, the air-conditioning system is so constructed that the controller 33 receives through the indoor unit operation controllers 30a to 30c the operation mode of each indoor unit and the temperature difference between a set temperature and inhaled air temperature of each indoor unit, the present invention is not limited to such structure, and signals indicative of the operation mode and the temperature difference can be input to the controller 33 in a different manner.

Although in the above embodiment, a variable rotation frequency type of compressor is utilized as a volume control type compressor to be able to adjust the rotational frequency of the compressor, thereby controlling the volume of the compressor, the present invention is not limited to such case. The present invention is also applicable to a case wherein a plurality of compressors are arranged and the number of driving compressors is adjusted. Compressors which can carry out volume control can be utilized to embody the present invention.

Although in the above embodiment, the outdoor fan is used as the heat exchanging amount changing means for the outdoor heat exchanger, and the revolution of the outdoor fan is controlled to adjust heat exchanging amount, the present invention is not limited to such case. The present invention is applicable to any manner wherein the air volume of the outdoor heat exchanger can be adjusted. A plurality of outdoor fans can be arranged, and the number of driving fans can be controlled to offer a similar effect.

A plurality of outdoor heat exchangers can be arranged in parallel, and the number of driving outdoor heat exchangers can be controlled to adjust the total heat exchanging amount of the outdoor heat exchangers.

Although in the above embodiment, the room temperature is detected based on the temperature of air inhaled into each indoor unit, for example, a temperature sensor can be provided in the room with each indoor unit in it, independently of the indoor unit, to detect the room temperature.

Even if the outdoor unit is connected to indoor units having different rated capacity, the operation mode or the rated capacity of the outdoor unit can be input to the controller 33 to accurately detect the operation mode, thereby optimizing operation control.

Next, the refrigerant system of the air-conditioning system according to the third embodiment of the present invention will be described. FIG. 16 is a schematic

diagram showing the entire structure of the refrigerant system of the air-conditioning system according to the third embodiment of the present invention. FIG. 17 to FIG. 19 illustrate the operation of room cooling and room heating according to the embodiment of FIG. 16. FIG. 17 illustrates room cooling only or room heating only. FIG. 18 and FIG. 19 illustrate room cooling and room heating concurrent operation. FIG. 18 illustrates the case where room heating is principally performed (room heating operation capacity is greater than room cooling operation capacity), and FIG. 19 illustrates the case where room cooling is principally performed (room cooling operation capacity is greater room heating operation capacity). FIG. 20 is a schematic diagram showing the entire structure of the refrigerant system of the modified air-conditioning system according to the third embodiment of the present invention. Since the same reference numerals as those of FIG. 1 will be used throughout the drawings to refer to the same or like parts, their repeated description will be omitted.

In this embodiment, although three indoor units are connected with an outdoor unit in the same manner as the related art, four or more indoor units may be connected with an outdoor unit in the same method.

In addition, although the outdoor unit 1 of the air-conditioning system includes a compressor 2, a four-way valve 3, an outdoor heat exchanger 4, a check valve 5, an expansion valve 6, a receiver 7, and an accumulator 8, the check valve 5, the expansion valve, and the receiver 7 will be omitted in the drawings for convenience.

In the drawings, a reference numeral 29 represents a gas-liquid separator provided at the middle portion of the first connection pipe 13, which serves to divide the refrigerant into gas and liquid. A reference numeral 22 represents the third connection pipe that connects the first electric expansion valve 212 of each of the indoor units 9a to 9c with the gas-liquid separator 29 of the first connection pipe 13. A reference numeral 7 represents the receiver provided at the middle portion of the third connection pipe 22, and 23 represents the electric expansion valve, which is a second flow rate controller, provided at the third connection pipe 22. A reference numeral 25 represents a first temperature sensor provided at a pipe that connects the four-way valve 3 with the outdoor heat exchanger 4, and 26 represents a second temperature sensor provided at a heat exchanging tube which is substantially located at an intermediate location of the outdoor heat exchanger 4.

The operation of the aforementioned air-conditioning system according to

the third embodiment of the present invention will be described.

First, room heating operation will be described with reference to FIG. 17. A refrigerant gas of high temperature and high pressure discharged from the compressor 2 is guided from the outdoor to the indoor by the second connection pipe 14. The refrigerant gas is supplied to the indoor heat exchanger 10 through the three-way switching valve 20 of the respective indoor units 9a to 9c. The refrigerant is heat-exchanged (heated) in the indoor heat exchanger 10 and then condensedly liquefied. The liquefied refrigerant is supplied to the third connection pipe 22 through the first electric expansion valve 21 and then to the receiver 7. The refrigerant is depressurized at low pressure by the second electric expansion valve 23.

The depressurized refrigerant is supplied to the outdoor heat exchanger 4 of the outdoor unit 1 through the first connection pipe 13 after passing through the gas-liquid separator 29. The refrigerant is heat-exchanged in the outdoor heat exchanger 4 and then is inhaled to the compressor 2 in a gas state.

In this way, the circulation cycle is formed to carry out the room heating operation.

Subsequently, room cooling operation will be described with reference to FIG. 17. A refrigerant gas of high temperature and high pressure discharged from the compressor 2 is heat-exchanged in the outdoor heat exchanger 4 and then condensedly liquefied. The refrigerant is supplied from the first connection pipe 13 to the third connection pipe 22 through the gas-liquid separator 29 and then to the receiver 7 through the second electric expansion valve 23 which is fully opened.

Afterwards, the refrigerant is supplied to the respective indoor units 9a to 9c and depressurized at low pressure by the first electric expansion valve 21. The refrigerant is then supplied to the indoor heat exchanger 10 and heat-exchanged (cooled) with indoor air to evaporate in a gas state.

The gaseous refrigerant is inhaled to the compressor 2 through the second connection pipe 14 by the three-way switching valve 20. In this way, the circulation cycle is formed to carry out the room cooling operation.

Next, the flow of the refrigerant when room heating is principally performed under room cooling and room heating concurrent operation will be described with reference to FIG. 18. First, a refrigerant discharged from the compressor 2 is supplied from the second connection pipe 14 to the respective indoor units 9b and 9c through the three-way switching valve 20. The refrigerant is heat-exchanged

(heated) in the indoor heat exchanger 10 and condensedly liquefied. The flow rate of the liquefied refrigerant is controlled so that it may slightly be supercooled. Then, the refrigerant is supplied from the first electric expansion valve 21 to the third connection pipe 22.

Some of the refrigerant is supplied to the room cooling indoor unit 9a and is depressurized by the first expansion valve 21. Then, the refrigerant is supplied to the indoor heat exchanger 10 and heat-exchanged (cooled) there to evaporate in a gas state. The gaseous refrigerant is supplied to the first connection pipe 13 through the three-way switching valve 20.

Meanwhile, the other refrigerant is supplied to the receiver 7 and then depressurized at low pressure by the second electric expansion valve 23. Then, the refrigerant is supplied from the third connection pipe 22 to the gas-liquid separator 29.

The refrigerant is joined with the refrigerant from the room cooling indoor unit 9a and is supplied to the outdoor heat exchanger 4 through the first connection pipe 13. The refrigerant is heat-exchanged in the outdoor heat exchanger 4 to evaporate in a gas state. Finally, the refrigerant returns to the compressor. In this way, the circulation cycle is formed to carry out the flow of the refrigerant when room heating is principally performed.

Further, the flow of the refrigerant when room cooling is principally performed in room cooling and room heating concurrent operation will be described with reference to FIG. 19. As shown in FIG. 19, a refrigerant discharged from the compressor 2 is supplied to the outdoor heat exchanger 4. The refrigerant is heat-exchanged in the outdoor heat exchanger 4 to become a gas-liquid type two-phase of high temperature and high pressure. The refrigerant is supplied to the gas-liquid separator 29 of the first connection pipe 13.

The refrigerant is separated into gas and liquid by the gas-liquid separator 29 and then supplied to the indoor. The gaseous refrigerant separated by the gas-liquid separator 29 is supplied to the room heating indoor unit 9a through the three-way switching valve 20. The refrigerant is heat-exchanged (heated) in the indoor heat exchanger 10 and condensedly liquefied. The refrigerant is then supplied from the first electric expansion valve 21 to the third connection pipe 22.

Meanwhile, the liquid refrigerant separated by the gas-liquid separator 29 is supplied to the receiver 7 through the second electric expansion valve 23 of the third connection pipe 22.

At this time, the flow rate of the refrigerant passing through the third connection pipe 22 is controlled based on a signal from a liquid level detector (such as a known float switch) in the gas-liquid separator 29 so that the liquid level in the gas-liquid separator 29 is within a predetermined range.

Specifically, when the liquid level is higher than the predetermined range, the opening degree of the second electric expansion valve 24 is increased. When the liquid level is lower than the predetermined range, the opening degree of the second electric expansion valve 24 is decreased.

Under this control, only the liquid refrigerant is always passing through the third connection pipe 22. The refrigerant from the receiver 7 is joined with the refrigerant from the room heating indoor unit 9a, and is supplied from the third connection pipe 22 to the room cooling units 9b and 9c.

After the refrigerant is depressurized at low pressure by the first electric expansion valves 21, the refrigerant is heat-exchanged (cooled) in the indoor heat exchangers 10 to evaporate.

The gaseous refrigerant is supplied to the second connection pipe 14 through the three-way switching valves 20, and returns to the compressor 2 again. In this way, the circulation cycle is formed to carry out the room cooling and room heating concurrent operation wherein room cooling is principally performed.

In this embodiment, the receiver 7 is arranged in the third connection pipe 22, and the first and second electric expansion valves 21 and 23 as the first and the second flow controllers control the superheating degree and the supercooling degree of the refrigerant in the outdoor heat exchanger 4 and the indoor heat exchanger 10 which serve as an evaporator or a condenser.

As a result, in case of room cooling only or room heating only, or under the room cooling and room heating concurrent operation, the fluctuation of the flow rate of the refrigerant due to the changes in the number of driving indoor units 9a to 9c or the change in air conditions can be adjusted by the receiver 7.

In the above embodiment, although the temperature sensor is provided at the heat-exchanging pipe substantially provided at the middle portion of the outdoor heat exchanger 4, the heat-exchanging pipe may be replaced by the first connection pipe 13 and the pressure sensor may be replaced by the temperature sensor.

In the above embodiment, although the indoor units 9a to 9c are comprised of the three-way switching valve 20, the indoor heat exchanger 10 and the first electric expansion valve 21, the indoor units 9a to 9c may be comprised of the

indoor heat exchanger 10 only and the three-way switching valve 20 and the first electric expansion valve 21 may be controlled by the air conditions of the indoor units 9a to 9c.

Now, the fourth embodiment of the present invention will be described in detail with reference to FIGS. 21 through 25. FIG. 21 is a schematic diagram showing the entire structure of the refrigerant system of the air-conditioning system according to the fourth embodiment of the present invention. FIG. 22 to FIG. 24 illustrate the operation of room cooling and room heating according to the embodiment of FIG. 21. FIG. 22 illustrates room cooling only or room heating only. FIG. 23 and FIG. 24 illustrate room cooling and room heating concurrent operation. FIG. 23 illustrates the case where room heating is principally performed (room heating operation capacity is greater than room cooling operation capacity), and FIG. 24 illustrates the case where room cooling is principally performed (room cooling operation capacity is greater room heating operation capacity). FIG. 25 is a schematic diagram showing the entire structure of the refrigerant system of the modified air-conditioning system according to the fourth embodiment of the present invention.

In this embodiment, although a single outdoor unit is connected to three indoor units, the explanation is also applicable to the case wherein the outdoor unit is connected to two or more indoor units. In FIG. 21, a reference numeral 1 represents the outdoor unit, and reference numerals 9a to 9c represent indoor units which are connected in parallel as described later and have the same structure as one another.

A reference numeral E represents a relay which includes a first branch joint, a second flow rate controller, and a second branch joint, as described later. A reference numeral 2 represents the compressor, 3 represents the four-way valve that switches the flow of the refrigerant of the outdoor unit, 4 represents the outdoor heat exchanger, and 8 represents the accumulator. The outdoor unit is connected with the compressor 2 and the four-way valve 4.

A reference numeral 10 represents three indoor heat exchangers. A reference numeral 13 represents the first connection pipe that connects the four-way valve 3 of the outdoor unit 1 with the relay E. Reference numerals 13a to 13c represent indoor first connection pipes corresponding to the first connection pipe 13 and connecting the indoor heat exchanger 10 of the indoor units 9a to 9c with the relay E. A reference numeral 14 represents the second connection pipe that connects an

outdoor heat exchanger 84 of the outdoor unit 1 with the relay E. Reference numerals 14a to 14c represent indoor second connection pipes corresponding to the second connection pipe 14 and connecting the indoor heat exchanger 10 of the indoor units 9a to 9c with the relay E. A reference numeral 20 represents the three-way switching valve which can switchedly connect the first connection pipes 13a to 13c to either the first connection pipe 13 or the second connection pipe 14. A reference numeral 21 represents the first flow rate controller connected to the second connection pipes 14a to 14c near to the indoor heat exchanger 10 and controlled depending on superheating amount on room cooling and supercooling amount on room heating at the outlet side of the indoor heat exchangers 10.

A reference numeral 16 represents a first branch joint comprised of the three-way switching valve 20 which can selectively connect the first indoor connection pipes 13a to 13c to either the first connection pipe 13 or the second connection pipe 14. A reference numeral 17 represents the second branch joint comprised of the indoor second connection pipes 14a to 14c and the second connection pipe 14. A reference numeral 23 represents the second flow rate controller which connects the first branch joint 16 with the second branch joint 17, and which can be opened and closed.

The operation of the embodiment which is constructed as stated above will be described. First, the case wherein room cooling only is performed will be described in detail in reference to FIG. 22.

As shown in a solid line arrow, the refrigerant of high temperature and high pressure discharged from the compressor 2 is heat-exchanged in the outdoor heat exchanger 4 and then condensedly liquefied after passing through the four-way valve 3. After that, the liquid refrigerant passes through the second connection pipe 14 and the second flow rate controller 23, and is supplied to the indoor units 9a to 9c through the second branch joint 17 and the indoor second connection pipes 14a to 14c.

The refrigerant supplied to the indoor units 9a to 9c is depressurized at low pressure by the first flow rate controller 21, and is heat-exchanged with indoor air in the indoor heat exchanger 10 to evaporate in a gas state, thereby cooling each room.

The gaseous refrigerant passes through the first connection pipes 13a to 13c, the three-way switching valve 20, the first branch joint 16, the first connection pipe 13, the four-way valve 3 for the outdoor unit, and the accumulator 8, and then is inhaled into the compressor 2. In this way, the circulation cycle is formed to carry

out room cooling operation.

At this time, the three-way switching valve 20 has a first port 20a closed and second and third ports 20b and 20c opened.

Next, the case wherein only room heating operation is performed will be described in detail with reference to FIG. 22. As indicated in arrows of dotted line, the refrigerant of high temperature and high pressure discharged from the compressor 2 passes through the four-way valve 3, the first connection pipe 14, the first branch joint 16, the three-way switching valve 20, and the indoor first connection pipes 13a to 13c. And then, the refrigerant is supplied to the indoor units 9a to 9c and heat-exchanged with indoor air to be condensedly liquefied, thereby heating each room.

The liquid refrigerant is supplied to the second connection pipes 14a to 14c and the second branch joint 17 through the first flow rate controller 21. Then, the refrigerant passes through the second flow rate controller 23. The refrigerant is depressurized to become gas-liquid two-phase state having low pressure by either the first flow rate controller 21 or the second flow rate controller 23.

The depressurized refrigerant is supplied to the outdoor heat exchanger 4 of the outdoor unit 1 through the second connection pipe 14. The refrigerant is heat-exchanged in the outdoor heat exchanger 4 to evaporate in a gas state. The gaseous refrigerant is inhaled into the compressor 2 through the four-way valve 3 and the accumulator 8. In this way, the circulation cycle is formed to carry out room heating operation.

At this time, the three-way switching valve 20 has ports taken the same positions as the room cooling operation as stated just above.

Now, the case wherein room heating is principally performed under the room cooling and room heating concurrent operation will be described in detail with reference to FIG. 23.

As indicated in arrows of dotted line, the refrigerant of high temperature and high pressure discharged from the compressor 2 is supplied to the relay E through the first connection pipe 13. The refrigerant passes through the first branch joint 16, the three-way switching valve 20, and the indoor first connection pipes 13a and 13b, and is supplied to the indoor units 9a to 9b which are expected to carry out room heating. The refrigerant is heat-exchanged with the indoor air in the indoor heat exchanger 10 to be condensedly liquefied, thereby heating each room.

The liquefied refrigerant passes through the first flow rate controller 21

which is substantially fully opened, is depressurized there to a predetermined extent, and flows into the second branch joint 17.

Some of the refrigerant passes through the indoor first connection pipe 14c, and is supplied to the indoor unit 9c which is expected to carry out room cooling. Then, the refrigerant passes through the first flow rate controller 21, is depressurized there, and then heat-exchanged in the indoor heat exchanger 10 to evaporate in a gas state, thereby cooling the room. Then, the refrigerant flows into the second connection pipe 14 through the three-way switching valve 20.

On the other hand, the other refrigerant flows into the first connection pipe 14 through the second branch joint 17 and the second flow rate controller 23. The refrigerant is joined with the refrigerant which has passed the indoor unit 9c, flows into the outdoor heat exchanger 4 of the outdoor unit 1, and is heat-exchanged in the outdoor heat exchanger 4 to evaporate in a gas state.

After that, the refrigerant is inhaled into the compressor 2 through the four-way valve 3 and the accumulator 8 in the outdoor unit. In this way, the circulation cycle is formed to carry out the room cooling and room heating concurrent operation wherein room heating is principally performed.

At this time, the three-way switching valve 20 connected to the indoor units 9a and 9b has a first port 20a closed and second and third ports 20b and 20c opened. The three-way switching valve 20 connected to the indoor unit 9c has a second port 20b closed, and first and third ports 20a and 20c opened.

Now, the case wherein room cooling is principally performed under the room cooling and room heating concurrent operation will be described in detail with reference to FIG. 24. As in indicated in arrows of solid line, the refrigerant of high temperature and high pressure discharged from the compressor 2 is heat-exchanged at an arbitrary amount in the outdoor heat exchanger 4 to become a gas-liquid two phase state having high temperature and high pressure. The refrigerant is then supplied to the relay E through the second connection pipe 14.

Some of the refrigerant passes through the first branch joint 16, the three-way switching valve 20 and the indoor first connection pipe 13c, and is supplied to the indoor unit 9c which is expected to carry out room heating. The refrigerant is heat-exchanged with the indoor air in the indoor heat exchanger 10 to be condensedly liquefied, thereby heating the room.

Then, the refrigerant flows into the second branch joint 17 through the first flow rate controller 21 which is substantially fully opened.

On the other hand, the other refrigerant is supplied to the second branch joint 17 through the second flow rate controller 23, and is joined with the refrigerant which has passed through the room heating indoor unit 9c. Then, the refrigerant is supplied to the indoor units 9a and 9b through the second branch joint 17 and the indoor second connection pipes 14a and 14b.

The refrigerant supplied to the indoor units 9a and 9b is depressurized at low pressure by the first flow rate controller 21, flows into the indoor heat exchanger 10. The refrigerant is then heat-exchanged with the indoor air to evaporate in a gas state, thereby cooling each room.

The gaseous refrigerant is inhaled into the compressor 2 through the indoor first connection pipes 13a and 13b, the three-way switching valve 20, the first branch joint 16, the first connection pipe 13, the four-way valve 3 for the outdoor unit, and the accumulator 8. In this way, the circulation cycle is formed to carry out the room cooling and room heating concurrent operation wherein room cooling is principally performed.

At this time, the three-way switching valve 20 connected to the indoor units 9a to 9c has first to third ports 20a to 20c taken the same positions as the room cooling and room heating concurrent operation wherein room heating is principally performed.

In the above embodiment, although the three-way switching valve 20 is provided to allow the indoor first connection pipes 13a to 13c to be selectively connected to either the first connection pipe 13 or the second connection pipe 14, opening and closing valves such as two electronic valves 40 and 41 can be substituted for the three-way switching valve 20 as shown in FIG. 25, and the electronic valves can be actuated in the same switching operation to offer a similar advantage.

Next, the fifth embodiment of the present invention will be described. FIG. 26 is a schematic diagram showing the entire structure of the refrigerant system of the air-conditioning system according to the fifth embodiment of the present invention. FIG. 27 to FIG. 29 illustrate the operation of room cooling and room heating according to the embodiment of FIG. 26. FIG. 27 illustrates room cooling only or room heating only. FIG. 28 and FIG. 29 illustrate room cooling and room heating concurrent operation. FIG. 28 illustrates the case where room heating is principally performed (room heating operation capacity is greater than room cooling operation capacity), and FIG. 29 illustrates the case where room cooling is

principally performed (room cooling operation capacity is greater room heating operation capacity). FIG. 30 is a schematic diagram showing the entire structure of the refrigerant system of the modified air-conditioning system according to the fifth embodiment of the present invention.

Since the same reference numerals as those of FIG. 1 will be used throughout the drawings to refer to the same or like parts, their repeated description will be omitted.

In this embodiment, although a single outdoor unit is connected to three indoor units, the explanation is also applicable to the case wherein the outdoor unit is connected to four or more indoor units.

Although the outdoor unit 1 of the air-conditioning system is comprised of the compressor 2, the four-way valve 3, the outdoor heat exchanger 4, the check valve 5, the expansion valve 6, the receiver 7, and the accumulator 8, the check valve 5, the expansion valve 6 and the receiver 7 will be omitted in the drawings for convenience.

In the drawings, a reference numeral 29 represents a gas-liquid separator which is provided at the middle portion of the first connection pipe 13 and serves to separate the refrigerant into gas and liquid.

A reference numeral 24 represents an electronic valve functioning as an opening and closing valve, 42 represents a capillary tube functioning as a flow rate controller, 28 represents a heat exchanger carrying out heat exchanging between the gas-liquid separator 29 of the third connection pipe 22 and the second electric expansion valve 23, and 27 represents a bypass pipe connected to the second connection pipe 14 separated by the middle portion in the height direction of the gas-liquid separator 29. The electronic valve 24, the capillary tube 42, and the heat exchanger 28 are provided at the middle portion of the bypass pipe 27.

The operation of the aforementioned air-conditioning system according to the fifth embodiment will be described in detail.

First, the flow of the refrigerant on room heating only will be described with reference to FIG. 27. A refrigerant gas of high temperature and high pressure discharged from the compressor 2 is guided from the outdoor to the indoor by the second connection pipe 14. The refrigerant gas is supplied to the indoor heat exchanger 10 through the three-way switching valve 20 of the respective indoor units 9a to 9c. The refrigerant is heat-exchanged (heated) in the indoor heat exchanger 10 and then condensedly liquefied.

The liquefied refrigerant is supplied to the third connection pipe 22 through the first electric expansion valve 21. The refrigerant is depressurized at low pressure by the second electric expansion valve 23 which is the second flow rate controller.

The depressurized refrigerant is supplied to the outdoor heat exchanger 4 of the outdoor unit 1 through the first connection pipe 13 after passing through the gas-liquid separator 29. The refrigerant is heat-exchanged in the outdoor heat exchanger 4 and then is inhaled to the compressor 2 in a gas state.

In this way, the circulation cycle is formed to carry out the room heating operation.

Next, room cooling operation will be described with reference to FIG. 27. A refrigerant gas of high temperature and high pressure discharged from the compressor 2 is heat-exchanged in the outdoor heat exchanger 4 and then condensedly liquefied. The refrigerant is supplied from the first connection pipe 13 to the third connection pipe 22 through the gas-liquid separator 29 and then to the respective indoor units 9a to 9c through the second electric expansion valve 23 which is fully opened.

Afterwards, the refrigerant supplied to the respective indoor units 9a to 9c is depressurized at low pressure by the first electric expansion valve 21. The refrigerant is then supplied to the indoor heat exchanger 10 and heat-exchanged (cooled) with indoor air to evaporate in a gas state.

The gaseous refrigerant is inhaled to the compressor 2 through the second connection pipe 14 by the three-way switching valve 20. In this way, the circulating cycle is formed to carry out the room cooling operation.

Next, the flow of the refrigerant when room heating is principally performed under room cooling and room heating concurrent operation will be described with reference to FIG. 28. First, a refrigerant discharged from the compressor 2 is supplied from the second connection pipe 14 to the respective room heating indoor units 9b and 9c through the three-way switching valve 20. The refrigerant is heat-exchanged (heated) in the indoor heat exchanger 10 and condensedly liquefied. The flow rate of the liquefied refrigerant is controlled so that it may slightly be supercooled. Then, the refrigerant is supplied from the first electric expansion valve 21 to the third connection pipe 22.

Some of the refrigerant is supplied to the room cooling indoor unit 9a and is depressurized by the first expansion valve 21. Then, the refrigerant is supplied to the indoor heat exchanger 10 and heat-exchanged (cooled) there to evaporate in a

gas state. The gaseous refrigerant is supplied to the first connection pipe 13 through the three-way switching valve 20.

Meanwhile, the other refrigerant is supplied from the third connection pipe 22 to the gas-liquid separator 29 after being depressurized at low pressure by the second electric expansion valve 23. Then, the refrigerant is joined with the refrigerant from the room cooling indoor unit 9a and is supplied to the outdoor heat exchanger 4 through the first connection pipe 13. The refrigerant is heat-exchanged in the outdoor heat exchanger 4 to evaporate in a gas state. Finally, the refrigerant returns to the compressor 2. In this way, the circulation cycle is formed to carry out the flow of the refrigerant when room heating is principally performed. The flow rate of the second electric expansion valve 23 is controlled to have a predetermined supercooling degree by detecting the refrigerant at the outlet of the outdoor heat exchanger 4.

Further, the flow of the refrigerant when room cooling is principally performed in room cooling and room heating concurrent operation will be described with reference to FIG. 29. As shown in FIG. 29, a refrigerant discharged from the compressor 2 is supplied to the outdoor heat exchanger 4. The refrigerant is heat-exchanged at an arbitrary amount in the outdoor heat exchanger 4 to become a gas-liquid type two-phase of high temperature and high pressure. The refrigerant is supplied to the gas-liquid separator 29 of the first connection pipe 13.

The refrigerant is separated into gas and liquid by the gas-liquid separator 29 and then supplied to the indoor. The gaseous refrigerant separated by the gas-liquid separator 29 is supplied to the room heating indoor unit 9a through the three-way switching valve 20. The refrigerant is heat-exchanged (heated) in the indoor heat exchanger 10 and condensedly liquefied. The refrigerant is then supplied to the third connection pipe 22 through the first electric expansion valve 21.

Meanwhile, the liquid refrigerant separated by the gas-liquid separator 29 is supplied to the bypass pipe 27 and the third connection pipe 22.

The liquid refrigerant supplied to bypass pipe 27 is depressurized at low pressure by the capillary tube 42, and then, the refrigerant is heat-exchanged in the third connection pipe 22 and the heat exchanging portion 28 (cooling refrigerant in the third connection pipe 22) to be gasified. After that, the gaseous refrigerant flows into the second connection pipe 14. The liquid refrigerant flowed into the third connection pipe 22 is cooled at the heat exchanging portion 28 by the refrigerant which is flowing through the bypass pipe 27 to become a slightly supercooled state.

Then, the refrigerant is joined with the refrigerant from the room heating indoor unit 9a through the second electric expansion valve 23, and flows into the room cooling indoor units 9b and 9c.

The refrigerant flowed into the room cooling indoor units 9b and 9c is depressurized at low pressure by the first electric expansion valves 21. The refrigerant is heat-exchanged in the indoor heat exchanger 10 to evaporate. The gaseous refrigerant flows into the second connection pipe 14 through the three-way switching valve 20, and returns to the compressor 2. In this way, the circulation cycle is formed to carry out the room cooling and room heating concurrent operation wherein room cooling is principally performed.

As explained, under the room cooling and room heating concurrent operation wherein room cooling is principally performed, the liquid refrigerant which is separated by the gas-liquid separator 29 and passing through the third connection pipe 22 becomes a supercooled state by means of heat exchange between the refrigerant passing through the third connection pipe 22 and the refrigerant passing through the bypass pipe 27.

As a result, even if there is pressure loss or the like because the length of the third connection pipe 22 extending from the gas-liquid separator 29 to the indoor units 9a-9c is long, the refrigerant can be prevented from being in a gas-liquid two phase state. This allows the refrigerant near to the inlet of the first electric expansion valves 21 of the room cooling indoor units 9b and 9c to be always in a liquid state regardless of the length of the third connection pipe 22. In this way, good flow controllability can be given to the first electric expansion valves 21, and the room cooling and room heating concurrent operation can be effectively realized. In addition, since the bypass pipe 27 is provided with the capillary tube 25 which functions as a flow rate controller whose flow resistance changes depending on the gas-liquid state of the refrigerant, there is no possibility that the gaseous refrigerant is flowing into the bypass pipe 27 at a great amount even if the liquid level of the refrigerant is lowered in the gas-liquid separator 29.

Therefore, the gaseous refrigerant continues to be supplied to the room heating indoor unit 9a at a suitable amount, preventing room heating capability from greatly lowering. Moreover, since the bypass pipe 27 allows the liquid level of the refrigerant in the gas-liquid separator 29 to maintain at a constant position and an excessive refrigerant can be stored in the accumulator 8, no receiver is required in the third connection pipe 22.

In the above embodiment, although the three-way switching valve 20 is provided to switchedly connect the first connection pipe 13 with the second connection pipe 14, it may be replaced by the opening and closing valves such as two electronic valves 40 and 41, as shown in FIG. 30.

In the above embodiment, although the indoor units 9a to 9c are provided with the first electric expansion valves 21, they may be provided with the temperature type electric expansion valve 12, the capillary tube 42, and the check valve 11. In case of the room cooling indoor units, the refrigerant may be depressurized at low pressure by the expansion valve 12. In case of the room heating indoor units, the refrigerant may be supplied from the indoor heat exchanger 10 to the third connection pipe 22 through the capillary tube 42 and the check valve 11.

In the above embodiment, although the third connection pipe 22 is provided with the second electric expansion valve 23, as shown in FIG. 30, an opening and closing valve such as an electric flow control valve 33 (e.g. ball valve) can be substituted for the second electric expansion valve 23. In addition, although the bypass pipe 27 branches from the substantially intermediate portion of the gas-liquid separator 29 in the height direction, the branching portion may be arbitrarily selected as long as it is located between the connecting position of the third connection pipe 22 and the opening of the first connection pipe 13.

Next, the sixth embodiment of the present invention will be described in detail. FIG. 31 is a schematic diagram showing the entire structure of the refrigerant system of the air-conditioning system according to the sixth embodiment of the present invention. FIG. 32 to FIG. 34 illustrate the operation of room cooling and room heating according to the embodiment of FIG. 31. FIG. 32 illustrates room cooling only or room heating only. FIG. 33 and FIG. 34 illustrate room cooling and room heating concurrent operation. FIG. 33 illustrates the case where room heating is principally performed (room heating operation capacity is greater than room cooling operation capacity), and FIG. 34 illustrates the case where room cooling is principally performed (room cooling operation capacity is greater room heating operation capacity). FIG. 35 is a flow chart showing the control flow of the controller. FIG. 36 is a schematic diagram showing the entire structure of the refrigerant system of the modified air-conditioning system according to the sixth embodiment of the present invention. Since the same reference numerals as those of FIG. 26 will be used throughout the drawings to refer to the same or like parts,

their repeated description will be omitted. In this embodiment, although a single outdoor unit is connected to three indoor units, the explanation is also applicable to the case wherein the outdoor unit is connected to four or more indoor units. The outdoor unit 1 of the air-conditioning system is comprised of the compressor 2, the four-way valve 3, the outdoor heat exchanger 4, and the accumulator 8.

In the drawings, reference numerals 30a to 30c represent indoor unit operation controllers, which output the operation modes of the indoor units 9a to 9c to the controller 33. Reference numeral 31 and 32 represents a temperature sensor such as a thermistor and a pressure sensor such as an electric pressure converter, which are provided extending from the first electric expansion valve 21 of the third connection pipe 22 to the second electric expansion valve 23. The controller 33 receives signals from the indoor unit operation controllers 30a to 30c, the temperature sensor 31, and the pressure sensor 32, and outputs a signal for adjusting the opening degree of the second electric expansion valve 23 and a signal for controlling the opening and closing of the electronic valve 24. In FIG. 35, x_{V2} represents the present command value on the opening degree of the second electric expansion valve 23. X^*_{v2} represents a new command value on the opening degree of the second electric expansion valve. $\triangle x_{v2}$ represents a variation between the present command value and the new command value. SC represents a supercooling degree of the refrigerant which is located in the portion of the third connection pipe 22 with the temperature sensor 31 and the pressure sensor 32. SC_H represents an upper limit of the controlled supercooling degree as a control target. SC_L represents a lower limit of the controlled supercooling degree as the control target.

The operation of the air-conditioning system of the sixth embodiment will be described in detail.

First, room heating operation will be described with reference to FIG. 32.

A refrigerant gas of high temperature and high pressure discharged from the compressor 2 is guided from the outdoor to the indoor by the second connection pipe 14. The refrigerant gas is supplied to the indoor heat exchanger 10 through the three-way switching valve 20 of the respective indoor units 9a to 9c. The heat-exchanged (heated) refrigerant is condensedly liquefied. At this time, the flow rate of the refrigerant supplied to the indoor units 9a to 9c is controlled by the first electric expansion valve 21 so that the refrigerant at the outlet of the indoor heat exchanger 10 becomes a slightly supercooled state. The liquid refrigerant is depressurized at low pressure by the first electric expansion valve 21 and then flows

into the third connection pipe 22. The controller 33 receives indoor units operation mode signals from the indoor unit operation controllers 30a to 30c. When the controller 33 detects that all indoor units 9a to 9c are under heating operation, the electronic valve 24 is fully closed, and the second electric expansion valve 23 is fully opened in accordance with the heating operation mode shown in the control flow chart of FIG. 35. As a result, the refrigerant condensedly liquefied in the indoor heat exchangers 10 passes through the second electric expansion valve 23, and flows into the outdoor heat exchanger 4 of the outdoor unit 1 through the first connection pipe 13. The refrigerant is heat-exchanged in the outdoor heat exchanger 4 and is inhaled into the compressor 2 in a gas state. In this way, the circulation cycle is formed to carry out room heating.

Next, room cooling only will be described with reference to FIG. 32.

A refrigerant gas of high temperature and high pressure discharged from the compressor 2 is heat-exchanged and condensedly liquefied in the outdoor heat exchanger 4. The liquefied refrigerant is supplied from the first connection pipe 13 to the third connection pipe 22 through the gas-liquid separator 29. The refrigerant is supplied to each of the indoor units 9a to 9c through the second electric expansion valve 23. At this time, the controller 33 receives the indoor unit operation mode signals from the indoor unit operation controllers 30a to 30c. If the controller 33 detects that it is now under the room cooling operation mode wherein all indoor units 9a to 9c are on room cooling, the second electric expansion valve 23 is fully opened as shown in the control flow chart of FIG. 35. The refrigerant supplied to the indoor units 9a to 9c is depressurized at low pressure by the first electric expansion valve 21. The refrigerant is then supplied to the indoor heat exchanger 10 and heat-exchanged (cooled) with room air to evaporate in a gas state. The gaseous refrigerant passes through the three-way switching valves 20, and is inhaled into the compressor 2 through the second connection pipe 14. In this way, the circulation cycle is formed to carry out room cooling. At this time, since the controller 33 makes the electronic valve 24 fully opened as shown in the flow chart of FIG. 35, some of the liquid refrigerant which has passed through the gas-liquid separator 29 flows into the bypass pipe 27. After the liquid refrigerant flowed into the bypass pipe 27 is depressurized at low pressure by the capillary tube 42, it is heat-exchanged in the third connection pipe 22 and the heat exchanging portion 28 (cooling the refrigerant in the third connection pipe 22), and flows into the second connection pipe 14 in a gas state. The liquid refrigerant flowed into the third

connection pipe 22 is cooled by the refrigerant in the bypass pipe 27 at the heat exchanging portion 26, becomes a slightly supercooled state, and flows into the indoor units 9a to 9c through the second electric expansion valve 23. Next, the case wherein room heating is principally performed under the room cooling and room heating concurrent operation will be described in detail with reference to FIG. 33 and FIG. 35. First, a refrigerant gas of high temperature and high pressure discharged from the compressor 2 is supplied to the respective room heating indoor units 9b and 9c through the three-way switching valve 20 by the second connection pipe 14. The refrigerant is heat-exchanged (heated) in the indoor heat exchanger 10 and condensedly liquefied. In this case, the flow rate of the refrigerant supplied to the indoor units 9a to 9c is controlled by the first electric expansion valve 21 so that the refrigerant at the outlet of the indoor heat exchanger 10 becomes a slightly supercooled state.

The liquefied refrigerant is depressurized at middle pressure by the first electric expansion valve 21 and then flows into the third connection pipe 22. Some of the refrigerant supplied to the third connection pipe 22 is supplied to the room cooling indoor unit 9a and depressurized again at low pressure by the first electric expansion valve 21. Then, the refrigerant is supplied to the indoor heat exchanger 10, heat-exchanged (cooled) there to evaporate in a slightly burst gas state, and supplied to the first connection pipe 13 through the three-way switching valve 20. Meanwhile, after the other refrigerant is depressurized at low pressure by the second electric expansion valve 23, it is supplied from the third connection pipe 22 to the first connection pipe 13. The refrigerant is joined with the refrigerant from the room cooling indoor unit 9a, heat-exchanged in the outdoor heat exchanger 4 to evaporate in a gas state, and inhaled into the compressor. In this way, the circulation cycle is formed to carry out the flow of the refrigerant wherein room heating is principally performed.

The operation of the second electric expansion valve 23 under this room cooling and room heating concurrent operation will be described with reference to FIG. 35.

The controller 33 receives the operation mode signals from the indoor unit operation controllers 30a to 30c, and signals from the temperature sensor 31 and the pressure sensor 32 which are arranged in the third connection pipe 22.

When the controller 33 detects based on such input signals that it is now under the room cooling and room heating concurrent operation wherein room

heating is principally performed, the controller 33 fully closes the electronic valve 24, and calculates, based on the signals from the temperature sensor 31 and the pressure sensor 32, the supercooling degree SC of the liquid refrigerant which is flowing through the third connection pipe 22.

In addition, the controller 33 determines whether SC is within the range of the control supercooling degrees SC_L to SC_H or not. When SC is within the range, the controller 33 outputs to the second electric expansion valve 23 the present command value X_{V2} on the opening degree for the second electric expansion valve 23 as a new command value X^*_{V2}.

When SC is greater than the upper limit SC_H of the control supercooling degree, the controller 33 outputs a value, which is obtained by adding the variation $\triangle X^*_{v2}$ to the present command value X_{v2}, to the second electric expansion valve 23 as a new command value X^*_{v2}. When SC is smaller than lower limit SC_L of the control supercooling degree, the controller 33 outputs a value, which is obtained by subtracting $\triangle X_{v2}$ from X_{v2}, to the second electric expansion valve 23 as a new command value X^*_{v2}.

In this way, the opening degree of the second electric expansion valve 23 can be adjusted to maintain the supercooling degree of the liquid refrigerant within a predetermined range, the liquid refrigerant being in the portion of the third connection pipe 22 where the temperature sensor 31 and the pressure sensor 32 are arranged.

The control supercooling degree in this portion is set so that it is slightly smaller than the control supercooling degree of the first electric expansion valves 21 corresponding to the room heating indoor units 9b and 9c.

Further, the case wherein room cooling is principally performed under the room cooling and room heating concurrent operation will be described with reference to FIG. 34 and FIG. 35.

As shown in FIG. 34, a refrigerant discharged from the compressor 2 is supplied to the outdoor heat exchanger 4. The refrigerant is heat-exchanged at an arbitrary amount in the outdoor heat exchanger 4 to become a gas-liquid type two-phase of high temperature and high pressure. The refrigerant is supplied to the gas-liquid separator 29 of the first connection pipe 13.

The refrigerant is separated into gas and liquid by the gas-liquid separator 29 and then supplied to the indoor. The gaseous refrigerant separated by the gas-liquid separator 29 is supplied to the room heating indoor unit 9a through the three-way

switching valve 20. The refrigerant is heat-exchanged (heated) in the indoor heat exchanger 10 and condensedly liquefied. The refrigerant is supplied to the third connection pipe 22 after being depressurized at middle pressure by the first electric expansion valve 21.

At this time, the flow rate of the refrigerant supplied to the room heating indoor unit 9a is controlled by controlling the opening degree of the first electric expansion valve 21, so that the refrigerant at the outlet of the indoor heat exchanger 10 becomes a slightly cooled liquid state.

Meanwhile, the liquid refrigerant separated by the gas-liquid separator 29 is supplied to the bypass pipe 27 and the third connection pipe 22.

The liquid refrigerant supplied to bypass pipe 27 is depressurized at low pressure by the capillary tube 42, and then, the refrigerant is heat-exchanged in the third connection pipe 22 and the heat exchanging portion 28 (cooling refrigerant in the third connection pipe 22) to be gasified. After that, the gaseous refrigerant flows into the second connection pipe 14.

The liquid refrigerant flowed into the third connection pipe 22 is cooled at the heat exchanging portion 28 by the refrigerant which is flowing through the bypass pipe 27 to become a slightly supercooled state. Then, the flow rate of the refrigerant is controlled by the second electric expansion valve 23. The refrigerant is depressurized at middle pressure and then joined with the refrigerant from the room heating indoor unit 9a.

The refrigerant flows from the third connection pipe 22 into the room cooling indoor units 9b and 9c. The refrigerant flowed into the room cooling indoor units 9b and 9c is depressurized at low pressure by the first electric expansion valves 21. The refrigerant is heat-exchanged (cooled) in the indoor heat exchanger 10 to evaporate.

At this time, the flow rate of the refrigerant supplied to the room cooling indoor units 9b and 9c is controlled by controlling the opening degree of the first electric expansion valve 21, so that the refrigerant at the outlet of the indoor heat exchanger 10 becomes a slightly overheated gas state.

The gaseous refrigerant flows into the second connection pipe 14 through the three-way switching valve 20, and returns to the compressor 2. In this way, the circulation cycle is formed to carry out the room cooling and room heating concurrent operation wherein room cooling is principally performed.

The operation of the second electric expansion valve 23 under this room

cooling and room heating concurrent operation wherein room heating is principally performed will be described with reference to FIG. 35.

The controller 33 receives the operation mode signals from the indoor unit operation controllers 30a to 30c, and the signals from the temperature sensor 31 and the pressure sensor 32 which are arranged in the third connection pipe 22.

When the controller 33 detects based on such input signals that it is now under the room cooling and room heating concurrent operation wherein room cooling is principally performed, the controller 33 fully opens the electronic valve 24, and calculates, based on the signals from the temperature sensor 31 and the pressure sensor 32, the supercooling degree SC of the liquid refrigerant which is flowing through the third connection pipe 22.

In addition, the controller 33 determines whether SC is within the range of the control supercooling degrees SC_L to SC_H or not. When SC is within the range, the controller 33 outputs to the second electric expansion valve 23 the present command value X_{V2} on the opening degree for the second electric expansion valve 23 as a new command value X^*_{V2}.

When SC is greater than the upper limit SC_H of the control supercooling degree, the controller 33 outputs a value, which is obtained by subtracting the variation $\triangle X_{v2}$ from the present command value X_{v2}, to the second electric expansion valve 23 as a new command value X^*_{v2}. When SC is smaller than lower limit SC_L of the control supercooling degree, the controller 33 outputs a value, which is obtained by adding $\triangle X_{v2}$ to X_{v2}, to the second electric expansion valve 23 as a new command value X^*_{v2}.

In this way, the opening degree of the second electric expansion valve 23 is controlled so that the supercooling degree of the liquid refrigerant which is in the portion of the third connection pipe 22 where the temperature sensor 31 and the pressure sensor 32 are arranged is maintained within a predetermined range.

As described above, under the room cooling and room heating concurrent operation wherein room cooling is principally performed, the liquid refrigerant which is separated by the gas-liquid separator 29 and passing through the third connection pipe 22 separated by the gas-liquid separator 29 becomes a supercooled state by means of heat exchange between the refrigerant passing through the third connection pipe 22 and the refrigerant passing through the bypass pipe 27. In addition, the refrigerant between the second electric expansion valve 23 and the first electric expansion valve 21 is controlled by the second electric expansion valve 23

to become a supercooled state.

As a result, even if there is pressure loss or the like because the length of the third connection pipe 22 extending from the gas-liquid separator 29 to the indoor units 9a to 9c is long, the refrigerant can be prevented from being in a gas-liquid two phase state. This allows the refrigerant near to the inlet of the first electric expansion valves 21 of the room cooling indoor units 9b and 9c to be always in a liquid state regardless of the length of the third connection pipe 22.

In this way, good flow controllability can be given to the first electric expansion valves 21, and the room cooling and room heating concurrent operation can be effectively realized.

In the above embodiment, although the temperature sensor 31 and the pressure sensor 32 which detect the supercooling degree of the third connection pipe 22 are arranged between the second electric expansion valve 23 and the first electric expansion valves 21, respectively, the present invention is not limited to such arrangement. As shown in FIG. 36, the temperature sensor and the pressure sensor can be arranged in each indoor unit so that the opening degree of the second electric expansion valve 23 is controlled to maintain the smallest one among the supercooling degrees of the indoor units within a predetermined range. This arrangement allows the refrigerant adjacent to the inlet of the first electric expansion valve 21 of the room cooling indoor unit to be always in a liquid state regardless of the length of the connection pipe 22 in each indoor unit and the difference in level of each indoor unit.

In the above embodiment, although the capillary tube 42 having a fixed flow rate is used as the third flow rate controller, the electric expansion valve such as the first and second flow rate controllers 21 and 23 may be used. In such case, the opening degree of the electric expansion valve is controlled by the controller 33.

In addition, the switching valve 20 of the indoor unit and the first electric expansion valve 21 may be provided either inside or outside a main body of the indoor unit. As described above, in the present invention, a single outdoor unit is connected with a plurality of the indoor units in parallel by the first connection pipe and the second connection pipe. One side of the indoor units is switchedly connected with the first connection pipe or the second connection pipe and connected with the other side of the indoor units through the first flow rate controller, and at the same time the other side of the indoor units is connected with the first connection pipe or the second connection pipe. The third connection pipe

provided with the second flow rate controller is provided at the pipe path. In this way, room cooling and room heating can selectively be carried out in each indoor unit.

Furthermore, in the present invention, the third connection pipe is additionally provided between the indoor units. The other connection pipes provided between the indoor units and the outdoor unit are used in the same manner as the related art. Therefore, high cost is not required and the installation of the elements is good.

In addition, in the present invention, the controller controls the operation mode of each of the indoor units and the opening degree of the first flow rate controller. The controller further controls the opening degree of the second flow rate controller based on the refrigerant state of the third connection pipe between the first and second flow rate controllers. In this case, the flow rate of the refrigerant can optimally be controlled and operation efficiency can be improved under the room cooling and room heating concurrent operation.

In the present invention, one side of the indoor units is switchedly connected with the first connection pipe or the second connection pipe, and the third connection pipe provided with the second flow rate controller at the middle portion connects the first flow rate controller at the other side of the indoor units with the first or second connection pipe. The controller detects the operation mode of each of the indoor units and the difference between the set temperature and each room temperature, and at the same time determines the driving state of the air-conditioning system as a whole and controls the volume of the compressor and the heat exchanging amount of the outdoor heat exchanger based on the detected data. In this way, the indoor units connected in parallel can selectively room cooling and room heating. As a result, it is possible to sufficiently exert room cooling and heating capability corresponding to room cooling and heating requirements, thereby improving driving efficiency.

In the air-conditioning system of the present invention, the gas-liquid separator is provided at the middle portion of the first or second connection pipe that connects the outdoor unit with the indoor units in parallel. One side of the indoor heat exchanger is switchedly connected with the first connection pipe or the second connection pipe through the three-way switching valve, and another side of the indoor heat exchanger is connected with the gas-liquid separator through the receiver or the flow rate controller by the third connection pipe. In this way, the

indoor units connected in parallel can simultaneously or selectively room cooling and room heating. Moreover, the flow rate of the refrigerant and gas-liquid state can be controlled properly. As a result, room cooling and room heating can be performed to correspond to room cooling and heating requirements of the space provided with the indoor units, thereby extending available range of the units.

In the air-conditioning system of the present invention, one side of the indoor unit is connected with the first branch joint switchedly connected to the first connection pipe or the second connection pipe, the other side is connected to the second branch joint connected with the second connection pipe through the first flow rate controller connected with the indoor units, the first branch joint and the second branch joint are connected with each other through the second flow rate controller, and a relay having the first branch joint, the second flow rate controller, and the second branch joint is interposed between the outdoor unit and the indoor units so that the first and second connection pipes are connected between the outdoor unit and the relay. In this way, room cooling and room heating can be performed selectively or simultaneously in the indoor units.

Further, the relay is provided between the two connection pipes that connect the outdoor unit with the indoor units, and two reciprocating connection pipes are provided between the outdoor unit and the relay and between the relay and the indoor units without additional pipes. In this case, the installation work required for the pipes is good, and the expenditure for such installation work is inexpensive.

In the air-conditioning system of the present invention, the gas-liquid separator is provided at the middle portion of the first connection pipe or the second connection pipe that connects the outdoor unit with the indoor units, one side of the indoor heat exchanger is switchedly connected with the first connection pipe or the second connection pipe through the three-way switching valve, the other side of the indoor units is connected with the gas-liquid separator provided at either the first connection pipe or the second connection pipe through the flow rate controller by the third connection pipe, the gas-liquid separator and the first or second connection pipe provided no gas-liquid separator are connected to the bypass pipe through the opening and closing unit and the flow rate controller, and the heat exchanging portion is provided in the bypass pipe to exchange heat between the gas-liquid separator of the third connection pipe and the flow rate controller. In this way, the flow rate of the refrigerant and the gas-liquid state can be controlled properly. As a result, room cooling and room heating can be performed to correspond to room

cooling and heating requirements of the space provided with the indoor units, thereby extending available range of the units.

Further, in case where room cooling is principally performed under the room cooling and room heating concurrent operation, even if the third connection pipe is long and pressure loss is great, the refrigerant flowing into the third connection pipe can be a single phase one of the liquid state. Moreover, since the gaseous refrigerant does not flow into the bypass pipe at a large amount, room cooling and room heating can be performed stably and efficiently.

In the air-conditioning system of the present invention, one side of the indoor units is switchedly connected with the first or second connection pipe, the gas-liquid separator is provided at the middle portion of the first connection pipe connected to the outdoor heat exchanger, the third connection pipe is provided with the second flow rate controller and connects the first flow rate controller at the other side of the indoor units with the gas-liquid separator, the bypass pipe connects the gas-liquid separator with the second connection pipe and is provided with the heat-exchanging portion exchanging heat among the pipe path opening and closing unit, the third flow rate controller, and the third connection pipe below the third flow rate controller, and the controller controls the opening degree of the second flow rate controller based on the operation mode of each of the indoor units and the refrigerant state of the connection pipe between the first and second flow rate controllers and at the same time controls opening and closing of the pipe path opening and closing unit. In this way, room cooling and room heating can be performed selectively or simultaneously in the indoor units connected in parallel. In addition, since the flow rate of the refrigerant and the gas-liquid state can be controlled properly, room cooling and room heating can optimally be performed to correspond to room cooling and heating requirements of the space provided with the indoor units, thereby improving driving efficiency.

WHAT IS CLAIMED IS:

1. An air-conditioning system comprising: a single outdoor unit including a compressor, a four-way valve, an outdoor heat exchanger, and an accumulator; a plurality of indoor units connected in parallel to the outdoor unit through a first connection pipe and a second connection pipe; a switching valve switchedly connecting one side of the indoor units with the first and second connection pipes; and a third connection pipe having one side connected to the other side of the indoor units through a first flow rate controller and the other side connected to

either the first connection pipe or the second connection pipe through a second flow rate controller.

2. The air-conditioning system according to claim 1, further comprising a controller controlling the opening degree of the second flow controller depending on the opening degree of the first flow controller and the conditions of the refrigerant in the third connection pipe between the first and second flow controllers.

3. The air-conditioning system according to claim 1, further comprising a controller controlling the volume of the compressor and the heat exchanging quantity of the outdoor heat exchanger depending on operation modes of the respective indoor units and difference between set temperatures for the respective indoor units and room temperatures in respective rooms provided with the indoor units.

4. The air-conditioning system according to claim 1, wherein the other side of the third connection pipe is connected to the first or second connection pipe through a gas-liquid separator, and a receiver is connected between the first and second flow controllers in the third connection pipe.

5. The air-conditioning system according to claim 1, further comprising a relay connecting the outdoor unit with the indoor units, having a switching valve, a first branch joint which connects the second flow rate controller and the switching valve to the first and second connection pipes, and a second branch joint which connects the second flow rate controller with the first flow rate controller.

6. An air-conditioning system comprising: a single outdoor unit including a compressor, a four-way valve, an outdoor heat exchanger, and an accumulator; a plurality of indoor units connected in parallel to the outdoor unit through a first connection pipe and a second connection pipe; a switching valve switchedly connecting one side of the indoor units to either the first connection pipe or the second connection pipe; a gas-liquid separator provided in either the first connection pipe or the second connection pipe; a third connection pipe having one side connected to the other side of the indoor units through a first flow rate controller, and having the other side connected to the gas-liquid separator through a second flow rate controller; a bypass pipe having one side connected to the gas-liquid separator through an opening and closing unit and a flow rate controller and having the other side connected to the first or second connection pipe provided no gas-liquid separator; and a heat-exchanging portion provided in the bypass pipe, carrying out heat exchange between the gas-liquid separator and the second flow

rate controller.

7. The air-conditioning system according to claim 6, further comprising a controller controlling the opening degree of the second flow rate controller and the opening and closing unit depending on operation modes of the respective indoor units and the conditions of a refrigerant in the third connection pipe between the first and second flow rate controllers.